COORDINATED HIGHWAYS ACTION RESPONSE TEAM
STATE HIGHWAY ADMINISTRATION

CHART System Architecture
Revision 8

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Revision	Description	Pages Affected	Date
0	Initial Release	All	9/5/00
1	Update for R1B4 and incorporation of Video into CHART II		6/30/05
2	Updates for R2B3, R3B1, R3B3, R3B3 CHART releases		12/11/2009
3	Updates for R4 CHART Release		04/29/2010
	Updates to reflect client comments		04/30/2010
4	Updates for CHART R5 Release		09/28/2010
5	Updates for CHART R6 Release		01/11/2011
6	Updates to address comments from D. Lineweaver		01/13/2011
7	Updates for CHART R7 Release		06/29/2011
8	Updates for CHART R8 Release		09/05/2011

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INTRODUCTION

1.1 Scope

This document defines the CHART system design and architecture. The document is divided into three major sections for presenting the overall design and architecture. Section 2 presents an overview of the design methodology used; a summary of design studies conducted to date, currently underway, or planned, and a discussion of design issues. Section 3 contains the hardware and software system design and architecture along with a proposed release strategy. Section 4 concludes with operations scenarios, a description of the user interface to the system, and descriptions of the operations environment.

1.2 Applicable Documents

Relevant documents associated with the system design are listed in the table below.

Table 1-1 Document References

Requirements and Vision
1. CHART II System Requirements, May 5, 2000, M361-RS-002R2.
2. CHART II Business Area Architecture Report, August 23, 2000, M361-BA-005.
3. CHART Video Software Requirements, June 2005
4. CHART R2B3 Requirements, October 2006
5. CHART Business Area Architecture, January 2007, W01-BA-001
6. CHART R3B1 Updated Software Requirements Revision 2, January 2008, W009-WS-001R2
7. CHART Business Area Architecture Revision 1, January 2008, W01-BA-001R1
8. CHART R3B2 Updated Software Requirements Revision 3, September 2008, W011-RS-002R3
9. CHART Business Area Architecture Revision 2, October 2008, W01-BA-001R2
10. CHART R3B3 Updated Software Requirements Revision 2, November 2009, WO15-RS-001R2
11. CHART Business Area Architecture Revision 3, December 2009, WO001-RS-001R3
12. CHART R4 Updated Software Requirements Revision 1, March 2010, WO17-RS-001R1
13. CHART Business Area Architecture Revision 4, April 2010, WO001-RS-001R4
14. CHART R5 Updated Software Requirements Revision 1, March 2010, WO18-RS-001R1
15. CHART Business Area Architecture Revision 5, September 2010, WO001-RS-001R5
16. CHART R6 Updated Software Requirements, August 2010, WO19-RS-001
17. CHART R7 Updated Software Requirements, February 8 2011, WO21-RS-001

Design
18. CHART II R1B1 High Level Design, July 16, 1999, M361-DS-001R0
19. CHART II R1B1 Detailed Design, January 21, 2000, M361-DS-002R0
20. CHART II R1B1 GUI High Level Design, January 21, 2000, M361-DS-003R0
21. CHART II R1B1 GUI Detailed Design, January 21, 2000, M361-DS-004R0
22. CHART II R1B2 High Level Design, May 17, 2000, M361-DS-005R0
23. CHART II R1B2 Servers Detailed Design, May 2000, M361-DS-006R0
24. CHART II R1B2 GUI Detailed Design, May 2000, M361-DS-007R0
25. CHART II R1B3 High Level Design, January 2001, M362-DS-009R0
26. CHART II R1B3 Servers Detailed Design, March 2001, M362-DS-011R0
27. CHART II R1B3 GUI Detailed Design, March 2001, M362-DS-010
28. CHART II R1B4 NTCIP Driver High Level Design, December 2001
29. CHART II R1B4 NTCIP Driver Detailed Design, May 2002
30. CHART Lite 2.0 System Design Document, April 2005
31. CHART II R2B1 Design, February 2006, M362-DS-019
32. CHART R2B2 Design, March 2006, M362-DS-020
33. CHART R2B3 Design, November 2006
34. CHART R3B1 Detailed Design, July 2007, W009-DS-001
35. CHART R3B2 Detailed Design, July 2008, W011-DS-001R2
36. CHART R3B3 Detailed Design, December 2008, W015-DS-001
37. CHART R4 Detailed Design Revision 1, March 2010, WO17-DS-001R1
38. CHART R5 Detailed Design Revision 1, March 2010, WO18-DS-001R1
39. CHART R6 Detailed Design, September 2010, WO19-DS-001
40. CHART R7 Detailed Design, March 2 2011, WO21-DS-001
Studies
41. Java Benefits and Risk Analysis, M361-AR-001R0, July 7, 1999
42. C++/Java Performance Comparison for Distributed ITS Control Systems, M361-AR-002R0, March 30, 1999
43. CHART II Java Feasibility Investigation, M361-AR-003R0, July 1, 1999
44. CORBA ORB Evaluation for CHART II, M361-AR-004R0, March 19, 1999
45. Maryland Department of Transportation (MDOT) Intelligent Transportation System Transformation Report, M361-AR-005R0, Draft
46. An Assessment of Architecture Approaches for Data Integration and Archiving,

M361-AR-006R0, December 3, 1999
47. Addendum to the Technical Memorandum for An Assessment of Architecture Approaches for Data Integration and Archiving, M361-AR-007R0, December 3, 1999
48. Summary of the Interviews for CHART II Data Needs and Requirements of Potential Users of an Archived Data User Service, M361-AR-007R0, December 3, 1999
49. FMS SNMP Interface Tool Selection, M303-AR-001R0, March 21, 2000
50. CHART II High Availability Study, M361-AR-009R0, July 14, 2000
Management and Schedule
51. CHART II System Development Schedule, September 15, 2000, M361-MP-004

SYSTEM-LEVEL DESIGN OVERVIEW

2.1 Design Methodology

Catalyst^{SM} is the structured methodology that is used to manage and implement CHART and can be mapped to Maryland's SDLC. It is a total methodology for business change and complex system development, Catalyst has a framework that facilitates and guides application system development, integration, deployment, and operational services.

Some of the key design principles that have guided the development of CHART and will continue to guide the development are listed below.

- Drive Development with the Business Vision. Using Catalyst, all architectural, design, and implementation decisions are made in the context of the desired future. To that end significant effort has been invested in developing the business vision through the Business Area Architecture (BAA). The BAA serves as the baseline for the business vision and is a direct predecessor of this document.
- Reengineer Business Processes; Do Not Merely Re-Automate Them. Rethink the most effective way to automate the CHART traffic management system. How can the operator most effectively relate to traffic information gathered from around the state and employ that information to make real-time traffic management decisions?
- Orchestrate the Business Change. Catalyst directly addresses the three dimensions of organizational change: culture, work force structure, and competencies.
- Build a System to Satisfy User Requirements at the Time of Delivery. Traditional methodologies have assumed that system developers can develop and document *today* the detailed requirements for a system to be delivered one to three years in the future. These methodologies further presuppose that users always have a clear and detailed understanding of the kind of system they will need, and they ignore the fact that the users' understanding of what they need evolves with system use. Catalyst avoids this pitfall through an iterative development process and constant dialog with the client.
- Unite Providers and Users in Partnership. Catalyst departs from the traditional view and encourages a cooperative partnership between developer and user. It greatly reduces formal specification, provides for active user participation at almost every step, and builds and maintains consensus on a daily basis.
- Achieve Business Results with a Series of Small Successes. The record of large, all-or-nothing, multi-year development projects is dismal. The "get-it-right-the-first-time" mentality has meant huge specification documents, long periods of development with too little developer-user dialogue, and ultimate delivery of an inevitably disappointing system. In contrast, a "partnership" viewpoint presses for modules of development with the shortest possible time span.
- Apply Technology Aggressively. Catalyst encourages aggressive exploitation of technology by considering technology capabilities and opportunities during every phase of development.
- Follow an Architectural Blueprint in Development. The architectural blueprint provides the framework that supports a coordinated effort while allowing sufficient latitude for organizational learning and links the business vision and system design.

The Catalyst methodology provides structure to our efforts. However, it is also flexible enough to encompass a variety of individual design elements and techniques.

Five of these design elements are particularly critical to our current CHART design efforts:

- Iterative Requirements Identification, Analysis, and Management,
- An Open Systems Approach Consistent with the National ITS Architecture,
- Object Oriented Analysis, Design, and Implementation,
- System Prototyping, and
- An Incremental Approach to Deployment.

The importance of the use of Catalyst and the five key design elements above in the implementation of CHART are summarized in Table 2-1.

Table 2-1. Features and Benefits of the CHART Design Approach

Design Element	Benefit to CHART II
Catalyst	• Provides an integrated, comprehensive approach based on proven commercial and government experience • Is meant to be tailored to respond to MDSHA needs and requirements • Conforms with established government and industry standards (e.g., SEI's CMMI for Software) • Responds to complex, changing, and diversified environments • Supports diversified new development approaches, legacy systems, data migration, and change management.
Iterative Requirements Identification, Analysis, and Management	• Ensures continuous improvement throughout the life of the project • Provides a flexible process to ensure that all MDSHA requirements will be met • Reflects lessons learned from one-on-one discussions with MDSHA personnel and from system prototyping • Supports a true partnership with MDSHA personnel in that both Team CSC and MDSHA personnel are fully involved in all requirements decisions
An Open Systems Approach	• Ensures that all current and envisioned requirements will be met • Ensures consistency with the National ITS Architecture and emerging national ITS standards • Eases incorporation of legacy systems and communications with external systems • Permits interchangeability of system components • Facilitates system growth
Object Oriented Analysis, Design, and Implementation	• Has the ability to store complex data objects • Allows complex objects to be manipulated in an organized manner • Allows the building of new objects by combining properties of previously existing objects • Permits applications to be built that are easier to maintain and enhance than those used in previous design approaches • Provides for clearer and more robust implementations and applications to be built on top of other applications • Permits new applications to be built on old object-oriented applications without the need for restructuring the underlying data and access methodologies, thereby reducing development time
System Prototyping	• Identifies problems early in the development process • Permits MDSHA to "Fly before Buy" • Supports an iterative requirements and design process • Ensures a delivered system that is fully responsive to MDSHA needs
An Incremental Approach to Deployment	• Supports more manageable deployment • Develops an operating capability sooner • Incorporates user operating experience into later deliveries • Promotes high morale through a series of successes

2.2 Design Overview

The CHART system design is derived from the results of the BAA and requirements specification efforts and is guided by the CHART vision. Excerpted below is a description of the CHART concept of operations as defined in Appendix E of the BAA.

The CHART System concept of operations encompasses of four major categories of business objectives:

- CHART is intended to be a statewide traffic management system, not limited to one or two specific corridors of high traffic volumes, but expandable to cover the entire state as funds, resources, and roadside equipment become available to support traffic management.
- CHART is intended to be a coordination focal point, able to identify incidents, congestion, construction, road closures and other emergency conditions; and then able to direct the resources from various agencies, as necessary, to respond to recurring and nonrecurring congestion and emergencies. It should also manage traffic flow with traveler advisories and signal controls, and coordinate or aid in the cleanup and clearance of obstructions.
- CHART is intended to be an information provider, providing real-time traffic flow and road condition information to travelers and the media broadcasters, as well as providing real-time and archived data to other state agencies and local, regional, inter-state, and private sector partners.
- CHART is intended to be a 7 day per week, 24 hours per day operation with the system performing internal processing and status checks to detect failed system components and resetting or reconfiguring itself where appropriate, or notifying operators and/or maintenance staff where necessary for service.

The CHART system design provides MDSHA with a highly available, flexible, and scalable statewide highway traffic monitoring and management system.

The system provides high availability through:

- The geographic distribution of equipment and functions.
- Redundancy for critical components and data.
- Multiple communications paths.

The system provides flexibility through

- A modular design that allows new subsystems to be easily integrated.
- The presentation to the user of a single seamless system regardless of where the user is located.

The system provides scalability through

- A distributed architecture allowing incremental growth.

Figure 2-1 shows a high level view of the CHART system.

The CHART system consists of four major software systems.

1. CHART – The heart and brain of the CHART system. It provides the interface for the CHART GUI, traffic management functions, and CCTV distribution and control.
2. Field Management System (FMS) and Communication Services – This system provides device communications and device data distribution functions for CHART field devices.
3. CHART GUI Web Server – This server provides access to CHART functionality by users via a web interface.
4. Archive – This system archives CHART event and operations related data and provides query and reporting functions.

These software systems are supported by the MDOT Enterprise network infrastructure. The network infrastructure is a key supporting ingredient of the overall CHART system but is not itself part of CHART.

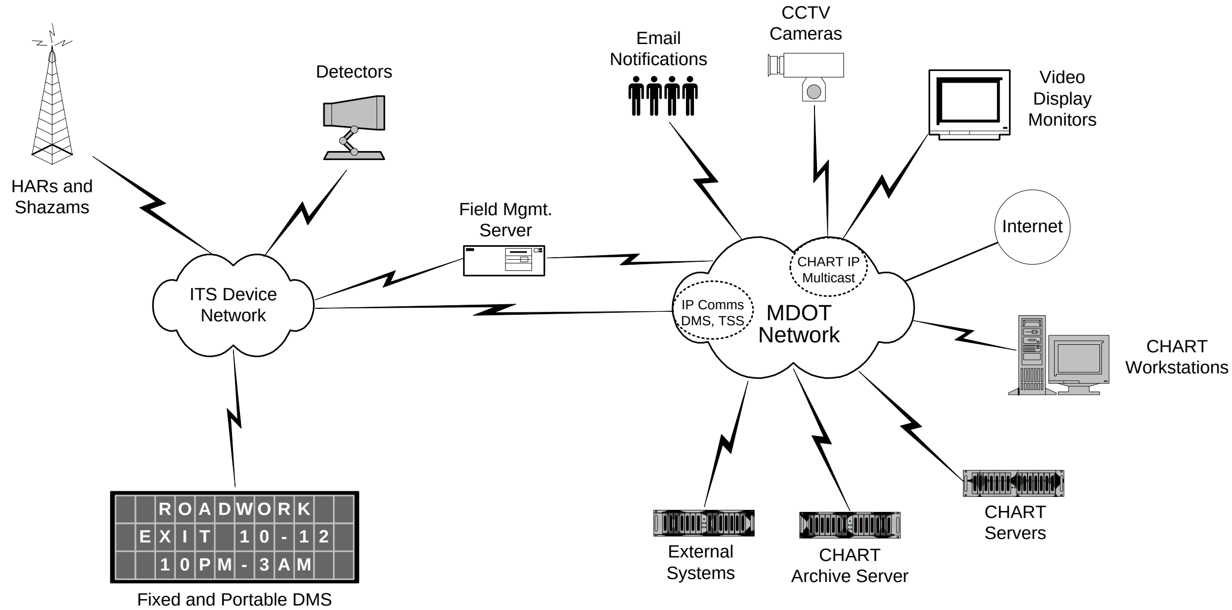


Figure 2-1. CHART System

The major external interfaces to the CHART system consist of:

1. CHART Web Server – The CHART Export Client is used to receive configuration and status updates from CHART via an HTTPS/XML interface. These updates relate to roadway conditions for publishing on the Web. This information includes incident reports, lane closure data, speed sensor data, DMS messages, and camera video.
2. CHART Internal Map – The CHART Export Client is used to receive configuration and status updates from CHART via an HTTPS/XML interface. These updates relate to roadway conditions for display with the CHART Mapping application. The data includes incident reports, lane closure data, DMS messages, and speed sensor data. CHART also queries the mapping database to get counties, roads, and road intersection data.
3. Emergency Operations Reporting System (EORS) – Legacy system providing information on road closures and road status.
4. Media – Commercial and public broadcasters via the Internet.
5. SCAN – SHA legacy system supplying weather sensor data.
6. CHART Reporting Tool – Generates reports from data on CHART databases.
7. University of Maryland Center for Advanced Transportation Technology (CATT) Lab as Regional Integrated Transportation Information System (RITIS) - Receives configuration and status updates from CHART via an HTTPS/XML interface. Provides SAE J2354 standard regional traffic events and TMDD standard DMS and TSS data via java messaging service connections.

8. Notification Recipients – Receive notification from CHART about significant events via e-mail or page/text.
9. INRIX – External system that provides travel time data to the CHART system. CHART connects to INRIX via an HTTPS/XML interface.
10. Vector – External (MdTA) system that provides toll rate data to the CHART system. The Vector system connects to CHART via an HTTPS/XML interface provided by CHART.
11. Streaming Flash Server (SFS) – External system used to manage transcoding of CHART video to a flash format for display on the CHART public web site and the Intranet map. CHART includes a capability to block specific cameras from being displayed on the public web site.

The high-level data flow diagram for the CHART system is shown in Figure 2-2.

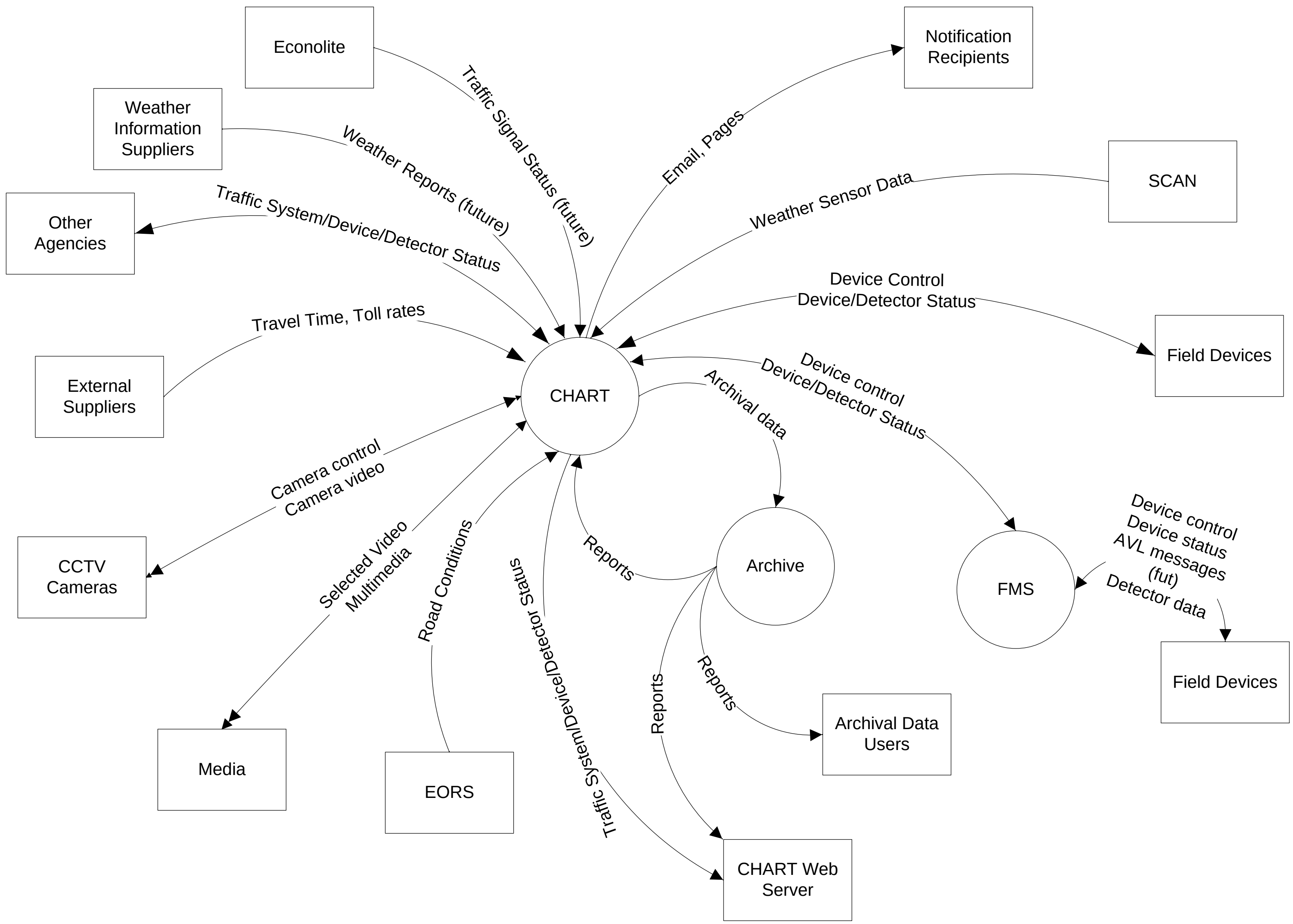


Figure 2-2. CHART System High Level Dataflow

2.3 Design Issues

This section presents an overview of unresolved issues, risks, or uncertainties in the system requirements, design, or interfaces and the steps planned to resolve them.

2.3.1 Simulation (future)

The University of Maryland has responsibility for the development of simulation tools for the CHART system. As discussed in the CHART BAA there are three modes of simulation support: real-time, off-line, and training. The concept for the operation of the simulation tools is presented in the BAA report however the actual capabilities of the tools are yet to be determined. It is expected that the simulation tools will be prototyped in order to validate the concepts presented in the BAA. In order to provide the University of Maryland with early access to real data for use in prototyping the simulation tools, the CHART system will capture archival data in an interim database prior to the availability of the CHART archive server. This data will be imported into the archival system once the archive is operational but will also be available for limited use prior to the deployment of the archive. To minimize any impact on the CHART system the simulation package is treated as a separate subsystem. This will facilitate the independent and parallel development of the simulation package and the rest of the CHART system.

2.3.2 Visioning

2.3.2.1 CHART Visioning Task

The CHART Visioning Task had originally started in December 1999 with the purpose of planning for future functionality of the CHART Program. The CHART Visioning Task was charged with examining ways in which CHART could better communicate with each MDOT modal, MDTA and several local jurisdictions throughout Maryland.

The objective of this task is to perform a high-level multi-modal needs/requirements analysis from a CHART/roadway traffic management perspective that will result in a Functional Vision Document. This document will be developed in a 3-phase approach and will yield 4 work products:

1. A functional vision document specific to the CHART Program functions being scheduled for implementation, including video, FMS and CHART on the Web.
2. A functional vision beyond the currently scheduled CHART Program features for multi-modal operations.
3. A functional vision beyond the currently scheduled CHART Program features for multi-agency operations.
4. Executive level presentation for Phase 1 results and next steps, Phase 2 results and next steps, and Phase 3 and next steps.

The Near Term Functional Vision focused on the functions and features of CHART system software, video and FMS hardware and software and CHART on the Web.

Phase 2 of the functional visioning task was to have a CHART-centric focus. This task will be restricted to the data, information and other types of coordination between CHART and the MDOT Modals. This is a first step towards defining the level of integration required between CHART and the MDOT Modals.

The scope of Phase 3 was to explore the potential relationships CHART will build with local jurisdictions, organizations and agencies.

2.3.2.2 CHART Business Area Architecture

The CHART Visioning Task has continued forward with an update to the CHART Business Area Architecture in February, 2011.

The key recommendations for success that were identified by BAA participants included:

- Connection to SHA Signal System – a communications infrastructure needs to be designed, funded and implemented.
- Detection – Many of CHART's requirements defined in this document can only be partially reached unless a detection infrastructure (leased or built) can be implemented.
- Communications – Integration with 911 Centers and support of RITIS. CHART should help guide RITIS into a 24/7 fully supported program.

These three key items, that are each projects unto themselves, will be the key areas that can take CHART to the next level of Traffic Management for the State of Maryland.

2.4 Standards

The CHART system is being designed to be as compliant as is currently possible with ITS national standards. The system design utilizes existing standards in the three areas of data storage, center to center communications and field communications.

In the area of data storage, the team is making an effort to utilize the Traffic Management Data Dictionary (TMDD) to define attributes stored in the database. An example of these attributes for CCTV cameras, are the cameras themselves, video switches etc. The TMDD contains the national ITS standard data definitions for data elements. Wherever practical, data elements that exist in the TMDD that are needed by the application use the TMDD definitions. Additional attributes that are needed to implement the CHART system requirements are added to these standard table definitions. However, the addition of these elements does not interfere with the ability to access the standard elements.

In the area of center to center communications, the CHART system design utilizes CORBA for transactions between internal software components. CORBA had been chosen as one of two approved methods of communication between ITS software components by the NTCIP Center to Center committee. When CHART was originally developed, the design team had referenced the burgeoning object model being developed by the Center to Center committee. At that time, however, it had not yet defined the system interfaces. Thus, the CHART system was developed to separate standard interfaces from those that are clearly CHART specific. CORBA has fallen out of favor in the IT industry since the original center to center communications standards were defined. As a result, CHART has moved towards an HTTPS/XML interface for receiving and sending data from/to external entities.

In the area of field communications, the CHART system design will be consistent with current national standards. This design supports the addition of NTCIP compliant devices, such as

DMSs and CCTV. The design team has also determined an approach for other standard interfaces that may be introduced in the future. CORBA provides a simple mechanism for adding interface support to existing interfaces through inheritance. This mechanism could be utilized when a new standard interface is released by the Center to Center committee. However, the standard of choice is the Extensible Markup Language (XML) for non-real time data. In the case of CHART data, XML will also be sufficient for near real-time data. XML is a markup language for documents containing structured information. Numerous applications as well as most web browsers already have XML support built-in. CHART will also ingest XML from external interfaces. RITIS sends CHART standards based XML data for traffic events, TSSs, and FMSs. CHART exports traffic event, DMS, TSS, HAR, and SHAZAM data in XML format as well.

SYSTEM DESIGN

This section provides an overview of the design of software and hardware elements of the CHART system.

3.1 System Overview

The CHART system architecture consists of a set of software and hardware Configuration Items (CIs).

There are five software CIs.

1. CHART – This CI consists of those subsystems providing direct support to the CHART operations staff.
2. FMS – This CI consists of those subsystems providing low speed communications support functions for traveler information devices, traffic detection devices, and other telecommunications support required by the CHART system.
3. COTS – This CI is a collection of all the COTS packages used by the CHART system. These are collected into a CI for configuration control purposes.
4. CHART Archive – This CI consists of subsystems supporting the archiving of CHART data and the analysis and reporting of archived data.
5. Database Instances – This CI collects the database schemas for the other CHART CIs for configuration control purposes.

There are five hardware CIs.

1. CHART Server – Supports CHART applications.
2. CHART Workstation – Supports CHART client-side functions for operations users. The need for this as a CI has been reduced by the adoption of the browser based CHART GUI as the one and only supported CHART GUI.
3. CHART GUI Web Server – Provides the conduit between the CHART services and the browser based interface GUI.
4. FMS Server – Support the FMS software CI subsystems.
5. CHART Archive Server – Supports the CHART archive software CI subsystems

Table 3-1 lists each software and hardware CI and the subsystems comprising the CI. The sections that follow provide functional descriptions for each CI.

The CHART system is dependent upon network services provided through the MDOT backbone network. The management and control of the network is outside the scope of this document.

Table 3-1 CHART System Configuration Items

CI Name	Software Subsystems
CHART	**Alert Management** **Audio** **AVL (future)** **Camera Control** **Communications Log Management** **Data Export Management** **Data Import Management** **Device Management** **Dictionary** **DMS Control** **HAR Control** **HAR Notification** **Message Library Management** **Notification Management** **Plan Management** **Resource Management** **Schedule Management** **SHAZAM Management** **Signals (future)** **Simulation (future)** **System Monitor (Watchdog)** **Traffic Event Management** **Traffic Sensor System Management** **Traveler Information** **User Management** **Utility** **Video Monitor Management**
FMS	**Port Manager** **Port Configuration Utility**
COTS (Runtime)	**JRE** **MS Visual C++** **Nuance Text to Speech** **Oracle** **JacORB Event Service** **JacORB ORB** **JacORB Trader** **Windows 2003**
COTS (Development/ Administrative)	**ArcServeIT** **ClearCase** **ClearQuest** **Requisite Pro** **NSIS** **Java SDK** **Krakatau**

CI Name	Software Subsystems
CHART Archive	**MS Visual C++** **Oracle** **Telelogic Tau UML** **Data Management Query** **Inetsoft Report Tool** **CHART Reporting System**
Database Instance	**Oracle**

A mapping between the business processes identified in the BAA and the CHART system CIs and subsystems appears in Table 3-2.

The following table presents the Business Process to Configuration Item matrix as aligned with the BAA revision in October, 2006.

Table 3-2 Business Process to Configuration Item Matrix

BAA Processes				CI	Subsystem
Administer Systems and Equipment					
Administer CHART Locations, Organizations and Users					
	a	Maintain CHART Organizations and Geographic Areas of Responsibility		CHART	User Manager
	b	Maintain CHART Functional Rights		CHART	User Manager
	c	Maintain CHART Roles		CHART	User Manager
	d	Maintain Users		CHART	User Manager
Maintain Message Libraries					
	a	Maintain Dictionaries		CHART	Dictionary
	b	Create Message Library Entity		CHART	Message Library Management
	c	Create DMS/HAR Message Template		CHART	Message Library Management
Manage CHART Control					
	a	Control Login		CHART	Resource Management

BAA Processes				CI	Subsystem
	b	Perform Shift Handoff (Incoming)		CHART	Resource Management
	c	Maintain Shift Handoff Report		CHART	Resource Management
	d	Use CHART Chat		CHART	Utility
	e	Control Logout and transfer Control		CHART	Resource Management
Install and Maintain Devices					
	a	Install Equipment/Devices		CHART	Device Management
	b	Put Equipment/Devices Online		CHART	Device Management
	c	Perform Routine Maintenance		CHART	Device Management
	d	Respond to Equipment/Device Outage		CHART	Device Management
Prepare for Events and Emergencies					
Maintain Decision Support Plan					
	a	Name Decision Support (DS) Plan		CHART	Plan Management
	b	Select DS Plan Conditions		CHART	Plan Management
	c	Associate Devices to DS Plan		CHART	Plan Management
	d	Associate Notifications and Resources to DS Plan		CHART	Plan Management
	e	Associate FITM or Alternative Route		CHART	Plan Management
	f	Set DS Plan Status		CHART	Plan Management
Maintain Traffic Plans					
	a	Maintain Roadway Plans, FITMs, and Alternate Routes		CHART	Utility, Plan Management
	b	Identify Roadways for Signal Control and Travel Time		CHART	Plan Management, Traveler Information Management
	c	Maintain Device Plans		CHART	Plan Management
Monitor Traffic and Roadways					
	a	Detect Conditions		CHART	TBD
	b	Record Conditions		CHART	Traffic Event Management
	c	Issue Alert or Post Notification		CHART	Alert Management, Resource Management
	d	Receive and respond to Alert		CHART	Alert Management
Manage Events					

BAA Processes				CI	Subsystem
Open event					
	a	Record Event Details		CHART	Traffic Event Management
			Specify Location and Impact	CHART	Traffic Event Management
			Capture Day/Date/Time	CHART	Traffic Event Management
			Capture Weather Conditions	CHART	Traffic Event Management
			Identify Event Source	CHART	Traffic Event Management
			Capture Related Events	CHART	Traffic Event Management
			Specify Nature of Problem	CHART	Traffic Event Management
			Determine Event Type	CHART	Traffic Event Management
	b	Deploy Resources			
			Verify Event Location and Specifics	CHART	Traffic Event Management
			Evaluate Event Response Recommendations	CHART	Traffic Event Management
			Select/Modify Course of Action	CHART	Traffic Event Management
			Execute Course of Action	CHART	Traffic Event Management
Respond To and Monitor Event					
	a	Monitor Event			
			Monitor Resource Status	CHART	Traffic Event Management
			Monitor Activities	CHART	Traffic Event Management
			Monitor Device Status	CHART	DMS Control, HAR Control
	b	Control On-scene Traffic			
	c	Manage Affected Area Traffic		CHART	Traffic Event Management
	d	Perform Scene Activities			
Close Event					
	a	Verify Scene Clear		CHART	Traffic Event Management
	b	Determine Event Closure or Transfer		CHART	Traffic Event Management, Resource Management
	c	Change Event Type		CHART	Traffic Event Management
	d	Record Event Closure		CHART	Traffic Event

BAA Processes				CI	Subsystem
					Management
	e	Conduct Post-event Analysis		Archive	Query and Report Generation
Manage Traffic					
Control Signals and Roadway Access				CHART	Traffic Event Management, Signals
Recommend Alternate Routes				CHART	Traffic Event Management
Calculate Travel Times				CHART	Utility, DMS Control, Traveler Information Management
Provide Traveler Information					
Broadcast Information				TBD	TBD
Maintain (External) Web Site Information					TBD
Provide Recorded Information				CHART	HAR Control
Provide CHART Information to Third Parties for Public Dissemination				CHART	Data Export Management
Provide Camera Video Feeds				CHART	Camera Control, Video Monitor Management
Manage CHART Performance					
Measure CHART Operations Performance				CHART	System Monitor
Measure Traffic Management					
Manage and Measure Device Performance					
	a	Check and Validate System and Status		CHART	DMS Control, HAR Control, TSS Control, Camera Control, Video Management Control
	b	Update Device/System Status		CHART	DMS Control, HAR Control, TSS Control, Camera Control, Video Management

BAA Processes				CI	Subsystem
					Control
	c	System Device Attempt Corrective Action			TBD
	d	Notify NOC of Device/System Status		CHART	Notification Management, DMS, HAR, TSS, Camera, Video Control, System Monitor
	e	Initiate Corrective Action and Follow to Closure			System Monitor
	f	Generate Device Reports		Archive	Query and Report Generation
Simulate CHART Operations and Traffic Management Performance				CHART	Simulation
Analyze Performance and Develop CHART Recommendations for Improvement				TBD, Archive	Query and Report Generation

3.2 Software CIs

Software Components

This section presents descriptions of the software CIs that comprise the CHART system. Major components of the CHART software are:

- The CHART Services which run on the CHART servers
- The CHART Database
- The CHART Archive
- The Field Management System (FMS)
- COTS packages

Design Principles

This section presents descriptions of the software CIs that comprise the CHART system. There are several key principles considered in the design of the CHART software CIs. These are exception processing, long running operations, and access control. These principles are described in detail below.

Exception Processing

Since CHART is a distributed object system, it is expected that any call to a remote object could cause an exception to be thrown. The system provides two levels of exception handling. The first is aimed at providing the user with immediate feedback on the failure status of the requested operation. The second is aimed at maintaining a log of system errors to enable system administrators to trace and correct problems. Each application maintains a running log file of software system status. Exceptions thrown by the applications contain a user displayable text status and a more detailed debug text status that is recorded in the application log file.

Long Running Operations

Many device control operations cannot be executed in a user responsive manner. Therefore the software has been designed to perform these operations in an asynchronous fashion. The initiator of a long running operation is provided the opportunity to supply a callback status object. This allows the application to supply progress information back to the initiating client as the operation proceeds. Each operation provides a final status that indicates overall success or failure.

A typical example is putting a message on a device such as a HAR. The system must dial up the device, obtain a connection between modems, confirm that the HAR controller is responding, send the message to the device, and finally disconnect the communications path. At each point in this process status information is available to the initiator via the callback status object. This allows, for example, the display of a progress window to inform an operator of the status of their request to put a message on a HAR.

Another example of a long running operation is putting a title on a Surveyor VFT camera. The camera interface requires a long running macro be used to set up each individual letter of the camera title or preset title. There may be other examples of long running operations such as queuing a request to control a camera. (Once a camera control session is established, routine camera control operations such as panning and tilting will be instantaneous operations, not subject to queuing, and therefore will not be classified as long running operations.)

Access Control

Users gain access to the system through a login process. As a result of this process they are provided an access token which contains a description of the functional rights that the user has previously been granted by a system administrator. The token also contains information describing the operations center that they are acting on behalf of. Each restricted system operation requires this token to be passed for functional right verification purposes. If the token contains the appropriate functional right to perform the operation the system will then verify that the user is logged in to the operations center that is currently responsible for any targeted shared resources.

The system provides for the concept of a shared resource. A shared resource is any resource that can be owned by a particular organization and is only allowed to be controlled by one operations center at a time. Access to a shared resource is controlled through the functional rights of the user attempting to gain control of the resource and through an arbitration scheme that prioritizes requests to the resource.

3.2.1 CHART Description

The architecture for the CHART system distributes complete system functionality to a number of districts throughout the State of Maryland. Each of these complete systems can provide full functionality for the devices connected to the system and objects created within that system (such as traffic events), and provides functionality for other district's systems that are available. Thus the absence of one district's server does not affect the ability of another district to use their own system or other systems that are available. Although the server deployment is spread across multiple sites, the user sees one large system, as CORBA is used to pull together objects served from the many deployment sites.

Figure 3-1 presents an overview of the CHART Architecture organized according to the Enterprise Architecture Framework as defined by the National Institute of Standards and Technology. This approach gives a holistic view of the enterprise and is organized into 5 layers:

- Enterprise Business Architecture Layer
- Enterprise Information Architecture Layer
- Enterprise Application Architecture Layer
- Enterprise Application Integration Architecture Layer
- Enterprise Infrastructure Architecture Layer

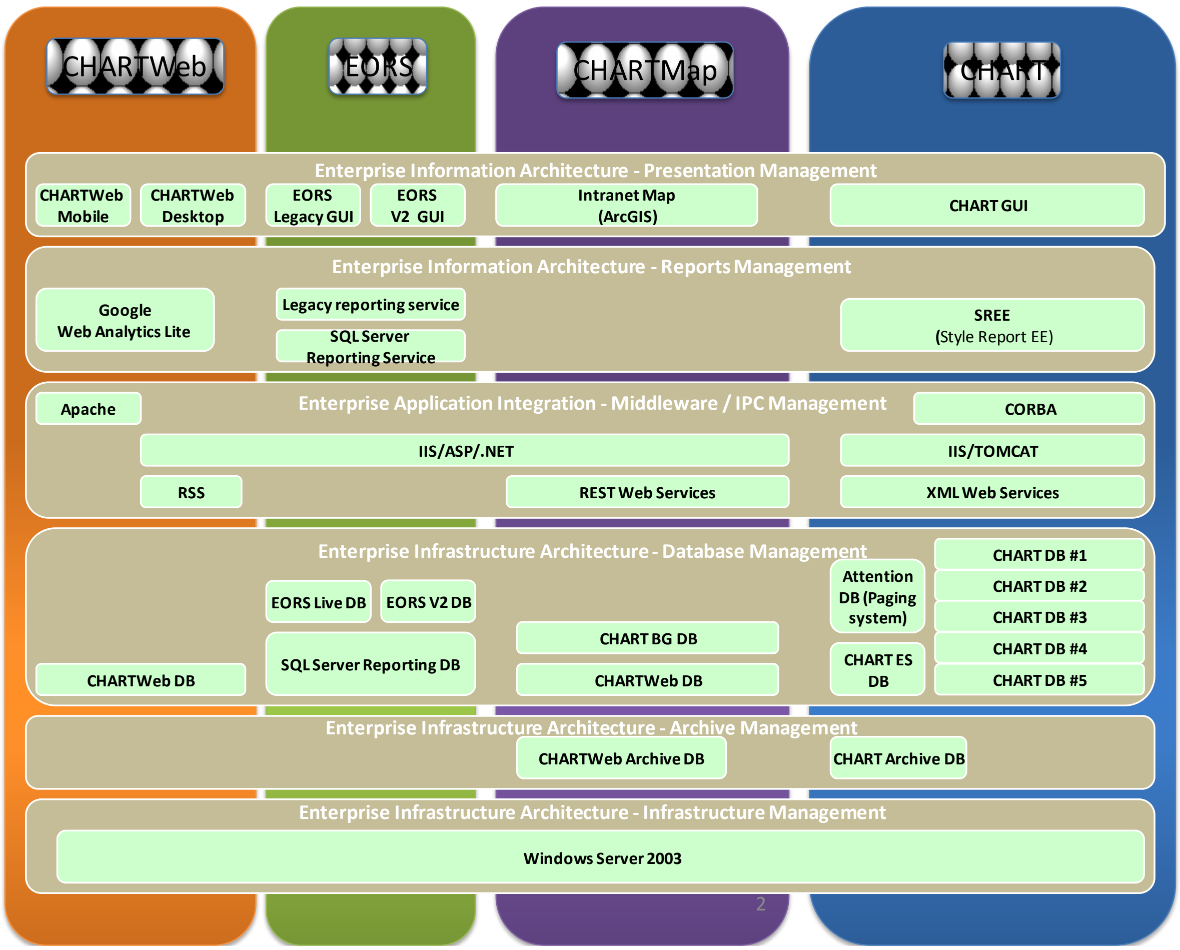


Figure 3-1. CHART Architectural Overview

The CHART GUI is able to locate the software objects at all deployment sites through the use of the CORBA Trading Service. A CORBA Trading Service runs at each deployment site. Each CHART service that publishes CORBA objects offers the objects through its local CORBA Trading Service. The GUI provides a unified view of the system, even though the system is actually distributed over multiple deployment sites.

In addition to showing the software objects throughout the system on a single interface, it is also necessary to reflect the current state of the software objects as they are changed during real time operations. The CORBA Event Service is used to allow objects to push changes in their state to the GUI, other back end CHART services, the CHART Data Exporter, or any other interested CORBA clients. Each deployment site has an instance of a CORBA Event Channel Factory, which is an extension of the CORBA Event Service that allows multiple event channels. Each CHART service whose objects are subject to real time changes will create one or more Event Channels in its local Event Channel Factory. Each event channel is earmarked for a specific class of events (such as DMS events). Each service that creates channels in the CORBA Event Channel Factory publishes the event channel in the CORBA Trading Service and then uses the channel to push events relating to object state, configuration updates, etc.

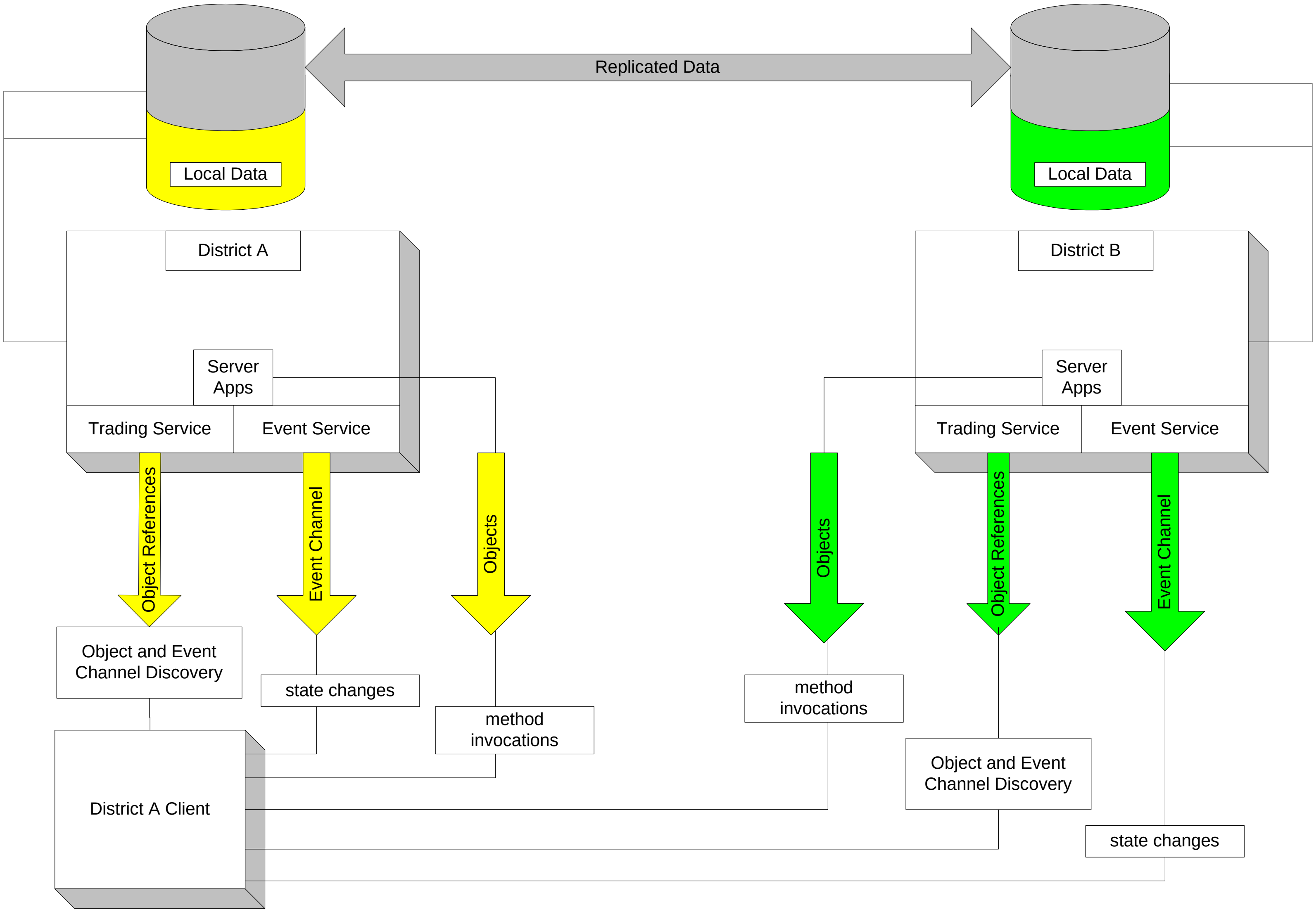
An interface that wishes to listen for events at a system wide level discovers all of the event channels via the CORBA Trading Service and registers itself as a consumer on each of the event channels. Using this scheme, an interface uses the Trading Service to discover all software objects and Event Channels regardless of their deployment site. The interface may then provide the user with a unified view of the system, both in the objects presented and the ability to show near real time updates of these objects. Since the nature of the system is dynamic, processes periodically rediscover new objects and event channels from known districts via the Trading Service. Figure 3-2 illustrates the relationship between the CORBA and Trading Event Services.

Starting with CHART Release 5, "external" entities receive CHART data via an HTTPS/XML interface rather than by the CORBA interface. The new HTTPS/XML interface provides security features and data filtering capabilities that are not readily available on the CORBA interface.

CHART background services which communicate with physical devices deployed along Maryland highways generally do so via TCP/IP for DMS and TSS. Starting with CHART R8, some HAR and SHAZAM device communications will also be via TCP/IP. For the remaining DMS, HAR, and SHAZAM devices, communications are done via FMS server. One or more CHART Communications Services run on each FMS in the system. The CHART background services requiring FMS services for this purpose are the DMS Service, and the HAR Service (which also serves SHAZAMs). Although currently all CHART TSSs utilize TCP/IP communications, the TSS Service may also utilize CHART Communications services running on an FMS. The communications between these services and the Communications Services are IIOP, over TCP/IP. Communications from the Communications Services out to the physical devices may be accomplished by telephone (via either POTS or ISDN modems, or via Telephony DTMF communications) or by direct serial connection. Telephone service is usually provided via landline, although cellular service occasionally needs to be utilized.

The remaining CHART background service controlling physical field devices is the Video Service. Video communication is accomplished via TCP/IP. Communication to CoreTec decoders is accomplished via proprietary CoreTec protocol over TCP/IP. Communication to iMPath decoders is accomplished via SNMP over TCP/IP, with published MIBs. CHART does not directly command either the iMPath or the CoreTec encoders; they are used only as a pass-through to pass camera control commands and responses to/from the attached cameras. CHART's communication with the encoders, then, is via TCP/IP with no proprietary protocol involved. Communications to the Vicon V1500 NTSC video switch is accomplished via a proprietary Vicon protocol over TCP/IP. Once a video connection is established, the video stream is directed from encoder to decoder via MPEG2 or MPEG4 over TCP/IP, and/or through a V1500 analog video switch. Starting with Release 5, the CHART software added support for multiple transmission devices for cameras. This was done to support the ongoing effort to transcode video into multiple formats in order to more effectively share video with various CHART partner organizations and the public. This infrastructure allows an MPEG2 encoded video source to be viewed on a monitor attached to an MPEG2 decoder, a monitor attached to an MPEG4 compatible SHA decoder, and a Flash video stream on the Intranet map, Public web site, and video web page on the State Wide Government Intranet (SWGI).

Figure 3-2. CORBA Trading and Event Services



Most CHART software objects used in this system are typical distributed software objects. Each of these objects is served from one and only one deployment site. The data inside an object pertains only to the instance of the object and operations pertain only to the instance of the object on which they are performed. Other parts of the system must go to the instance of an object to view the object's data or perform operations (via method invocations) on the object. For example, there is one and only one software object in the system that represents a specific DMS in the field. If an operation such as setting the message needs to be done to the Field DMS, the user interface must perform the operations on the one and only software object that represents the DMS.

The system includes classes whose instances do not act as the typical objects described above. Instead, each instance of the class provides access to exactly the same data. Multiple instances of the class serve as replicated software objects. Some examples of this type of object are the Dictionary, UserManager, and Communications Log. These objects are different than the rest of the objects in the system because it is required that the dictionary, user data, and communications log be shared throughout all deployment sites in the system. Using the same dictionary data throughout the system provides consistency in messages displayed on DMSs. Using the same user data throughout the system allows a user to log in at any site, even in the event of a catastrophe at the user's normal operating site.

While the design could accomplish this use of shared data through using single instances of the objects, this type of design would include single points of failure. Thus if the one and only one Dictionary object were not available, no messages would be able to be placed on a DMS anywhere in the system since the message contents could not be checked for banned words. To overcome these single points of failure, the replication feature of the DBMS will be used to replicate data to each deployment site's database. Each deployment site will have its own instances of the Dictionary, User Manager, and Communications Log objects that front end the replicated database. The system takes advantage of these redundant objects by first attempting to retrieve the object from the client’s home site. Failing that, it will fail-over to an alternate site’s instance of the target object.

3.2.1.1 Software Subsystems

The software subsystems comprising the CHART CI are briefly described below. The detailed descriptions of the business processes that are to be implemented in each subsystem have been presented in Section 4.3 of the BAA and are not repeated here (see Table 3-2 for a mapping of BAA business processes to CHART System CIs and subsystems).

3.2.1.1.1 Alert Management

This subsystem provides alert management and processing functions. It provides the methods to support the creation and delivery of alerts and maintains the status of alerts in the system. Alerts may be automatically created by applications or manually created by users. Alerts may be directed to an operations center where acknowledgement by a user is required. Alerts may also be caught by an application for automatic processing (e.g. a weather sensor alert may initiate the creation of a weather sensor alert event by the Traffic Event Management subsystem and the sending of a notification by the Notification Management subsystem).

Some example CHART alerts are listed below.

- Device Failure – used to alert centers of device failures
- Event Still Open Reminder – used to alert centers of events that have been left open for

- Duplicate Event – used to alert centers that there are multiple events at the same location.
- Travel Time – used to alert centers that there is a problem with the Travel Time interface or that a travel Time related threshold has been crossed..
- Toll Rate Alert – used to alert centers that there is a problem with the Toll Rate interface
- External Interface Alert – used to alert centers that there is a problem with one of the CHART external interfaces.
- External Event Alert – used to alert the centers that there is an external event of particular interest.
- Unhandled Resource – used to alert centers that there are unhandled resources such as an open traffic events or devices in maintenance mode that are controlled by center that has no logged in users.
- Transfer of Responsibility (future) – provides an alert to the receiving center of a transfer of responsibility to that center (e.g. transfer of responsibility for an open event)
- Incident from Detector (future)– alerts a center that detector data indicates a possible incident
- Mayday from AVL (future)– generated when an AVL equipped vehicle sends a Mayday message
- Weather Sensor (future) – generated when a weather sensor reports data outside of a set range (e.g. temperature below freezing)

Alerts that require a response within a specified time period are escalated up the center hierarchy if not acknowledged within the set time period.

The client side of alert management provides the user with the capability to manually generate an alert and to respond to alerts they receive.

3.2.1.1.2 Audio

This subsystem provides distributed access to a text-to-speech engine that is utilized by the HAR subsystem for the conversion of text format messages into audible data that can be downloaded to the HAR device for broadcast. It also provides the ability to stream audio data back to requesting clients for message preview purposes.

3.2.1.1.3 AVL (future)

This subsystem provides the interface between the AVL data feed, currently consumed by the Intranet map, and the CHART system. It is responsible for obtaining vehicle position and status information and providing a conduit for any two-way communications between an AVL equipped vehicle and the CHART system.

3.2.1.1.4 Camera Management

This subsystem provides cameras, camera configurations, distribution of video, and coordinate access to camera control functions. This subsystem also provides control access to video by users designated as Internet or media outlets.

3.2.1.1.5 Communications Log Management

This subsystem provides a general logging mechanism for operators to record communications and activities in a central repository. All recorded communications are made available to all other operators in near real time through the user interface. The communications log also provides a filtered searching capability that allows an operator to select entries for viewing. Users may select entries to convert to a traffic event. These entries will become the base entries in the traffic event's history log.

3.2.1.1.6 Data Export Management

The Data Export Management subsystem provides a mechanism to make CHART data available to external entities. This subsystem generates standards based, XML formatted data streams with pre-defined content. This data is provided via a secure HTTP interface. CHART exports ATIS J2354 based Traffic Event data, and TMDD based status and configuration data for TSS and DMS. CHART also exports CCTV, HAR, and SHAZAM configuration data.

3.2.1.1.7 Data Import Management

The Data Import Management subsystem provides a mechanism for CHART to ingest data from external entities. This data is currently made available by RITIS and includes Traffic event, DMS, and TSS data.

3.2.1.1.8 Device Management

This subsystem handles the control of device state functions (online, offline, maintenance mode) and the management of device arbitration queue entries.

3.2.1.1.9 Dictionary

This subsystem provides administrator managed collections of banned and known words. Banned words are those words that are not allowed to be displayed or broadcast on traveler information devices. Known words are used to provide spell checking and substitution suggestions when unknown words are detected.

3.2.1.1.10 DMS Control

This subsystem provides DMS control capabilities. It supplies support for multiple device manufacturer protocols. In addition, this subsystem provides the business logic required for arbitration of a particular DMS between competing traffic events.

3.2.1.1.11 HAR Control

This subsystem provides HAR control capabilities. It supplies support for manufacturer protocols used by SHA HAR devices. In addition, this subsystem provides the business logic required for arbitration of a particular HAR between competing traffic events.

3.2.1.1.12 HAR Notification

This subsystem provides management functions for the control of HAR notification devices such as SHAZAMs and DMS devices used as SHAZAMs.

3.2.1.1.13 Message Library Management

This subsystem provides message library management capabilities. It supports the creation of multiple message libraries for user defined stored messages, examples of which include DMS and HAR messages. Each message in a library can be assigned a category for user classification purposes.

3.2.1.1.14 Notification Management

This subsystem provides capabilities for managing the notification of personnel via page, or email.

3.2.1.1.15 Plan Management

This subsystem provides the ability to create macro type collections of device control commands. Each item in a plan associates a stored message with a traveler information device. These plans can be used to quickly construct traffic event response plans for traffic events that are recurring in nature or can be planned for ahead of time.

3.2.1.1.16 Protocol Handlers

Application objects known as device protocol handlers are provided as a high level interface to the FMS system for specific device control. These protocol handlers are coded to communicate with a specific device type. Handlers for device types can be added to the system as needed. The list of currently identified protocol handlers is shown below.

Dynamic Message Signs (DMS)

- FP9500
- FP2001
- FP1001
- TS3001
- Sylvia
- Display Solutions
- Addco
- NTCIP (v 2.35)

Highway Advisory Radio (HAR)

- Information Station Specialists (ISS) AP55
- Highway Information Systems (HIS) DR1500

SHAZAM

- Viking RC2A remote on/off controller

Each protocol handler provides methods used by application programs to perform specific functions supported by the device targeted by the protocol handler. For example, a typical DMS protocol handler has methods to set a message, blank the sign, reset, and poll the DMS.

Device protocol handlers do not store device status or configuration; they only provide an encapsulation of the device protocol and act as a utility for higher level applications that provide device control to an end user. The protocol handlers are provided a connected Port object through which they communicate with the device to fulfill a request.

3.2.1.1.17 Resource Management

This subsystem provides for management of user login sessions and the control of shared resources.

3.2.1.1.18 Schedule Management

This subsystem supports the creation, management, and execution of lists of actions to be performed at predetermined times.

3.2.1.1.19 Signals (future)

This subsystem provides an interface to the signals system in order to obtain traffic signal status information for use by the CHART system.

3.2.1.1.20 Simulation (future)

The Simulation subsystem is provided by the University of Maryland and integrates with the CHART II system.

3.2.1.1.21 System Monitor

This subsystem provides system health monitoring processes that run on each CHART server and FMS server. Each service application is monitored to determine if it is currently available. Alerts and/or Notifications are generated when services are found to be unavailable and self-recovery is attempted.

3.2.1.1.22 Traffic Event Management

This subsystem provides for the management and recording of information pertaining to traffic events that are currently being worked on by system operators. It also provides for the control of traveler information devices via a traffic event's response plan. The response plan is composed of system actions, including device control commands. When the plan is executed the system actions are performed and any device control actions result in an entry being placed on the arbitration queue for the target device.

Each traffic event maintains a running history log of actions performed and user comments. Additionally, each traffic event maintains records of devices controlled, resources notified and utilized, and a list of related events for offline reporting and statistical analysis purposes.

3.2.1.1.23 Traffic Sensor System Management

This subsystem provides control and data handling functions for traffic detector and speed measurement devices. Historical data summaries are compiled and archived. Current traffic detector information is compared with historical traffic detector information and alerts are generated for conditions exceeding specified tolerances.

3.2.1.1.24 Traveler Information Management

This subsystem ingests traveler information, including travel time data and toll rate data, data from external sources and makes it available to CHART for display in the CHART GUI and on DMS signs.

3.2.1.1.25 User Management

This subsystem provides the capability to create and manage user profiles and access rights.

3.2.1.1.26 Utility

The Utility subsystem provides various utility functions for the CHART system and collects processes that do not have a home elsewhere. These include notepad management, the chat function, FITM plan management, GIS map update functions, etc.

3.2.1.1.27 Video Monitor Management

This subsystem provides the ability for managing monitors, monitor configurations, and display of camera video.

3.2.2 FMS Description

The FMS provides communications services to CHART field devices. The FMS software, like the CHART CI, uses a set of distributed applications communicating via CORBA to provide a highly available system. Each FMS server is a standalone system capable of communicating with any field device for which it has a matching communications port type. All user interaction with the FMS is handled through the CHART user interface. The FMS infrastructure is being phased out in favor of direct TCP/IP communications with CHART field devices. As of CHART R8, TCP/IP communications are supported for all CHART field devices.

3.2.2.1 Software Subsystems

The software subsystems comprising the FMS CI are described below. All user interaction with the FMS subsystems is handled through the CHART client side applications.

3.2.2.1.1 Port Manager

The FMS software that manages access to communications resources is a Port Manager. A Port Manager is configured specifically for the hardware that it will manage. The communications resources are modeled in software as Port objects. Specific types of port objects exist for each type of communications resource that is supported, for example ISDN modems, POTS modems, and direct serial ports.

Upon startup of the FMS software, a Port Manager object is created and published to the CORBA trading service, making it available for discovery and use by other applications. The Port Manager creates port objects to represent each of the physical communications resources which it is configured to manage. The actual type of object created depends on the type of port, for each type of port object contains functionality specific to the resource it represents. After the port manager is started, it accepts requests for ports by other application software that has communications requirements.

Applications request Port objects by type and priority. When a request for a port is received, the Port Manager finds a port of the specified type that is not currently in use and returns a reference to the port object to the requester. If all instances of a requested type of port are in use, a timeout value supplied by the requester is used to determine how long the requester is willing to wait for a port to become available. In the event there are two or more requesters waiting for a port to become available, the priority is used to determine which requester gets the next available port.

Once a port is acquired, it is accessed directly by its user to perform functionality specific to the type of port, such as connecting to a remote modem and/or sending and receiving bytes.

After a requester has finished using a port, it releases the port back to the Port Manager. The port manager has a background process that reclaims ports as may be necessary if the user of a port is not well behaved.

3.2.3 COTS Description

The COTS CI collects all COTS packages into a single CI for configuration control purposes. This CI will be used to track the COTS packages and versions used. Below is a table listing all COTS packages used throughout the system (development, test, and operations).

Table 3-3 COTS Packages

Product Name	Description

Apache ActiveMQ	CHART uses this to connect to RITIS JMS queues
Apache Jakarta Ant	CHART uses Apache Jakarta Ant 1.6.5 to build CHART applications and deployment jars.
Apache Tomcat	CHART uses Apache Tomcat 6.0.18 as the GUI web server.
Apache XML-RPC	CHART uses the apache xmlrpc java library 3.1.2 protocol that uses XML over HTTP to implement remote procedure calls. The video Flash streaming “red button” (“kill switch”) API uses XML over HTTP remote procedure calls.
Attention! CC	CHART uses Attention! CC Version 2.1 to provide notification services.
Attention! CC API	CHART uses Attention! CC API Version 2.1 to interface with Attention! CC.
Attention! NS	CHART uses Attention! NS Version 7 to provide notification services.
Bison/Flex	CHART uses Bison and Flex as part of the process of compiling binary macro files used for performing camera menu operations on Vicon Surveyor VFT cameras.
CoreTec Decoder Control	CHART uses a CoreTec supplied decoder control API for commanding CoreTec decoders.
Dialogic API	CHART uses the Dialogic API for sending and receiving Dual Tone Multi Frequency (DTMF) tones for HAR communications.
DocExpressWord	CHART uses Telelogic DocExpressWord 4.1, to export diagrams from the Telelogic Tau UMP design tool into Microsoft Word.
Eclipse	Java development environment. CHART developers use Version 3.x.
Flex 3 SDK	The CHART GUI uses the Flex 3 SDK, version 3.1 to provide the Flex compiler, the standard Flex libraries, and examples for building Flex applications.
GIF89 Encoder	Utility classes that can create .gif files with optional animation. This utility is used for the creation of DMS True Display windows.
JDOM	CHART uses JDOM b7 (beta-7) dated 2001-07-07. JDOM provides a way to represent an XML document for easy and efficient reading, manipulation, and writing.
JacORB	CHART uses a compiled, patched version of JacORB 2.3.1. The JacORB source code, including the patched code, is kept in the CHART source repository.
Java Development Kit (SDK)	CHART uses 1.6.0_21.
Java Run-Time (JRE)	CHART uses1.6.0_21.
JavaService	CHART uses JavaService to install the server side Java software components as Windows services.
JAXB	CHART uses the jaxb java library to automate the tedious task

	of hand-coding field-by-field XML translation and validation for exported data.
JAXEN	CHART uses JAXEN 1.0-beta-8 dated 2002-01-09. The Jaxen project is a Java XPath Engine. Jaxen is a universal object model walker, capable of evaluating XPath expressions across multiple models.
JoeSNMP	CHART uses JoeSNMP version 0.2.6 dated 2001-11-11. JoeSNMP is a Java based implementation of the SNMP protocol. CHART uses for commanding iMPath MPEG-2 decoders and for communications with NTCIP DMSs.
JSON-simple	CHART uses the JSON-simple java library to encode/decode strings that use JSON (JavaScript Object Notation).
JTS	CHART uses the Java Topology Suite (JTS) version 1.8.0 for geographical utility classes.
Krakatau	CHART uses Power Software Krakatau PM, version 211, for source code metrics.
Microsoft SQL Server	CHART uses Microsoft SQL Server, Version 2005, for retrieving roadway location and EORS data.
Microsoft Visual C++	CHART uses Visual C++ Version 6, Service Pack 6 for C++ source code development and runtime.
Microsoft Windows 2003	CHART uses Microsoft Windows 2003 as its standard runtime platform for the CHART application, FMS, and GUI Web servers.
NSIS	CHART uses the Nullsoft Scriptable Installation System (NSIS), version 2.20, as the server side installation package.
Nuance Text To Speech	For text-to-speech (TTS) conversion CHART uses a TTS engine that integrates with Microsoft Speech Application Programming Interface (MSSAPI), version 5.1. CHART uses Nuance Vocalizer 4.0 with Nuance SAPI 5.1 Integration for Nuance Vocalizer 4.0.
OpenLayers	The Integrated Map feature uses the Open Layers JavaScript API 2.8 (http://openlayers.org/) in order to render interactive maps within a web application without relying on vendor specific software. Open Layers is an open source product released under a BSD style license which can be found at (http://svn.openlayers.org/trunk/openlayers/license.txt).
Oracle	CHART uses Oracle 10.1.0.5 as its database and uses the Oracle 10G JDBC libraries (ojdbc1.4.jar) for all database transactions.
O'Reilly Servlet	Provides classes that allow the CHART GUI to handle file uploads via multi-part form submission.
Prototype Javascript Library	The CHART GUI uses the Prototype Javascript library, version 1.6.1, a cross-browser compatible Javascript library provides many features (including easy Ajax support).

Rational ClearCase	CHART uses the IBM Rational ClearCase, version 7.0.0.0, tool for source code control.
Rational ClearQuest	CHART uses the IBM Rational ClearQuest, version 7.0.0, tool for tracking software problem reports.
Rational Requisite Pro	CHART uses the IBM RationalRequisitePro, version 7.0.0.2, tool for managing the CHART software requirements.
SAXPath	CHART uses SAXPath 1.0-beta-6 dated 2001-09-27. SAXPath is an event-based API for XPath parsers, that is, for parsers which parse XPath expressions.
Telelogic Tau UML	CHART uses the Telelogic Tau UML tool, version 4.8.0, for Object Oriented software design.
Velocity Template Engine	Provides classes that CHART GUI uses in order to create dynamic web pages using velocity templates.
Vicon V1500 API	CHART uses a Vicon supplied API for commanding the ViconV1500 CPU to switch video on the Vicon V1500 switch

3.2.4 CHART Archive Description

The CHART Archive CI is responsible for the archiving of CHART data and supports query, report generation, and data management functions on the archive data. All data is stored in an Oracle database.

3.2.4.1 Software Subsystems

The software subsystems comprising the CHART Archive CI are described below. The primary user interface to the CHART Archive for interactive query and report will be through a web browser.

3.2.4.1.1 Data Management

The Data Management subsystem handles the export and import of data to and from external systems. Data is imported from the CHART CI in the form of rows of information from the CHART database. The Data Management subsystem also receives detector data from the FMS CI. Detector data is received in raw (unprocessed) form and is stored in summarized form for quick access. Data export provides standard summary products for presentation to the public through the CHART web server.

3.2.4.1.2 Query and Report Generation

The Query and Report Generation subsystem provides archive system users with the ability to perform queries and to generate reports on archive data. The subsystem consists primarily of a COTS package with a Web interface. Users interact with the subsystem through a standard web browser. The selected product for this subsystem is InetSoft Report Writer.

3.2.5 Database

The design is based on the CHART Business Area Architecture, and the CHART System requirements. The database design consists of these major areas:

- User/system management
- Device configuration
- Device status
- Traffic event response planning
- Events and logging
- Alerts
- Notification
- Schedules
- System parameters
- Travel Routes
- Replication
- Archiving

The current overall CHART database design is illustrated in the detailed entity relationship diagrams presented in Figures 3-3 through 3-16.

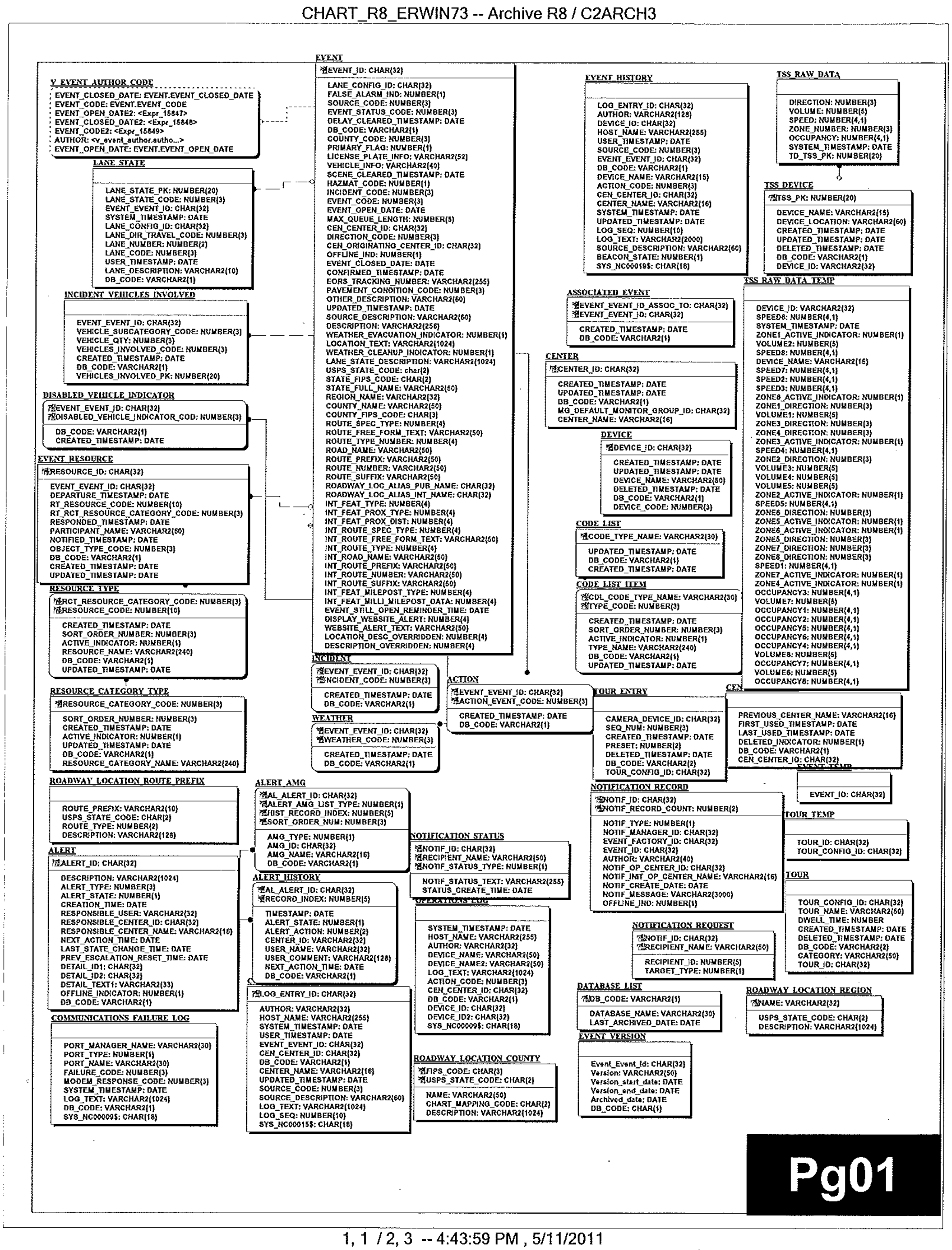


Figure 3-3. CHART ERD (1 of 14)

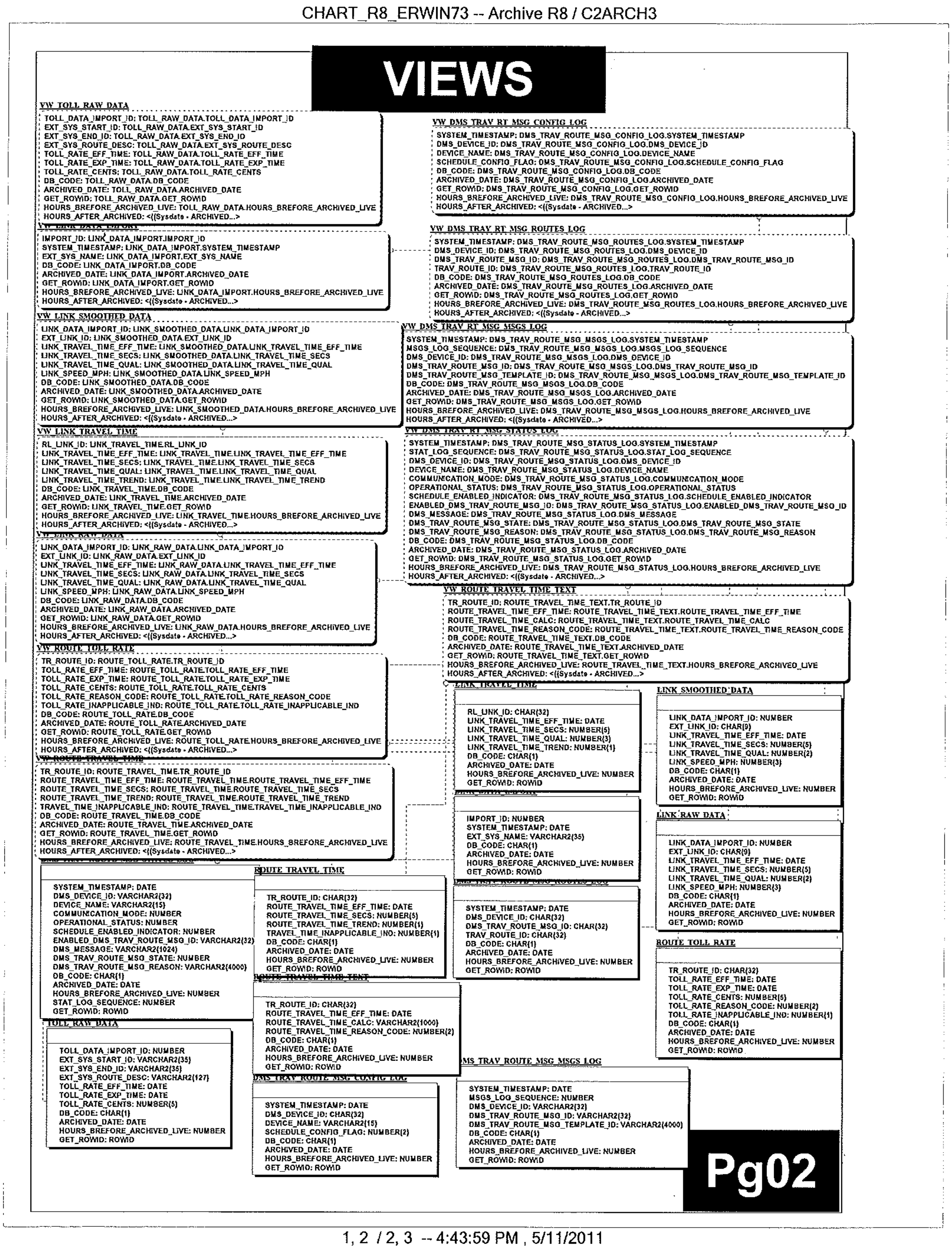


Figure 3-4. CHART ERD (2 of 14)

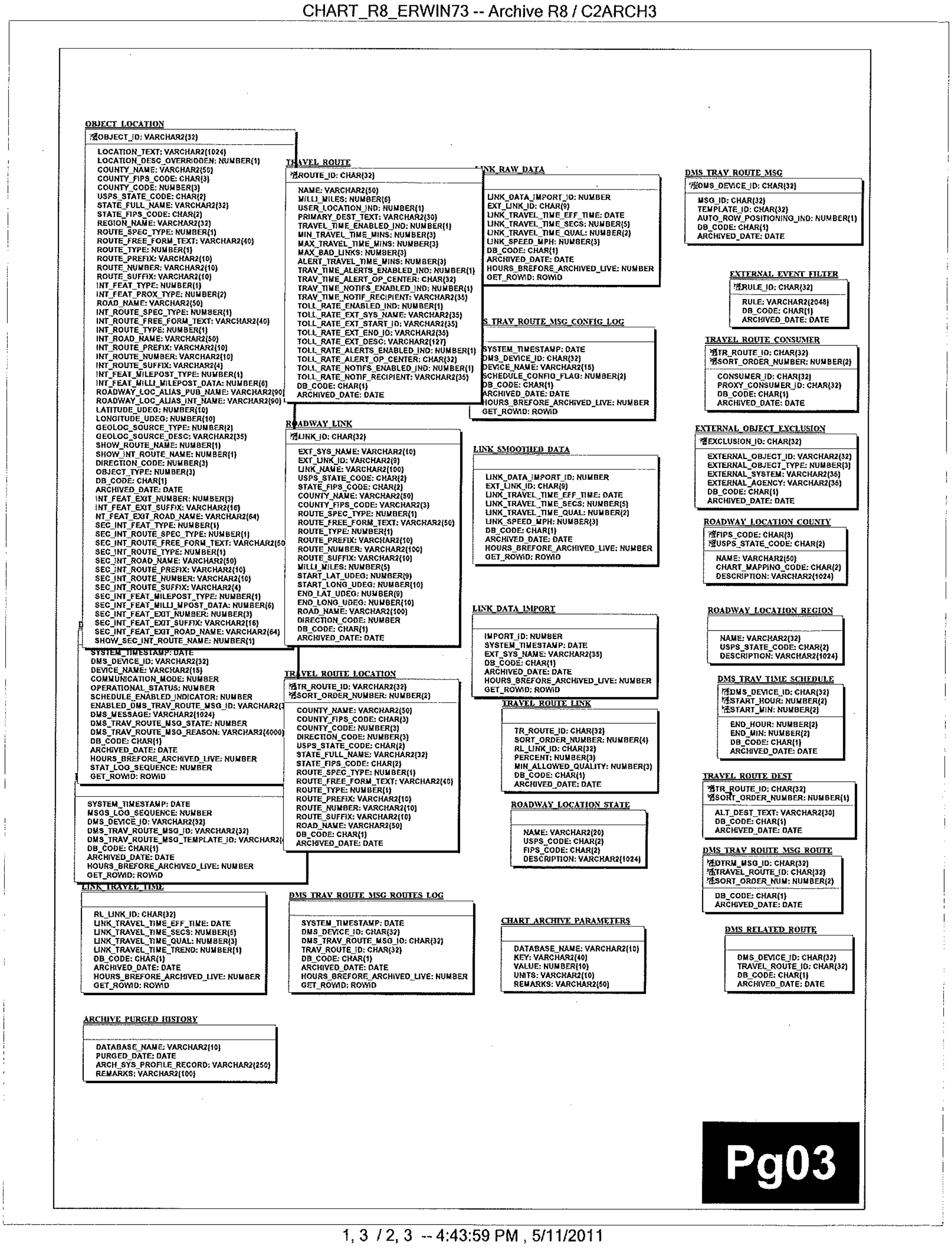


Figure 3-5. CHART ERD (3 of 14)

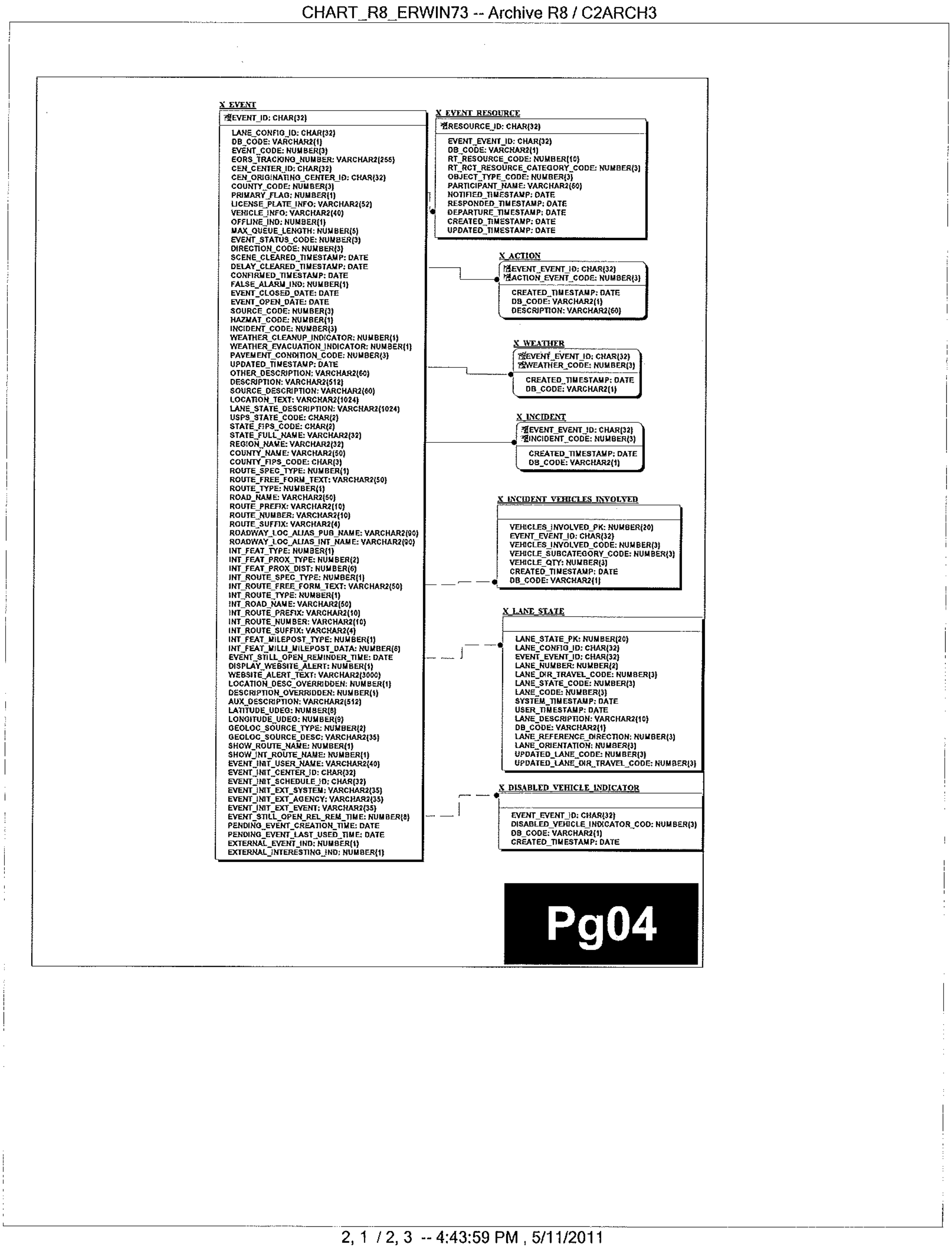


Figure 3-6. CHART ERD (4 of 14)

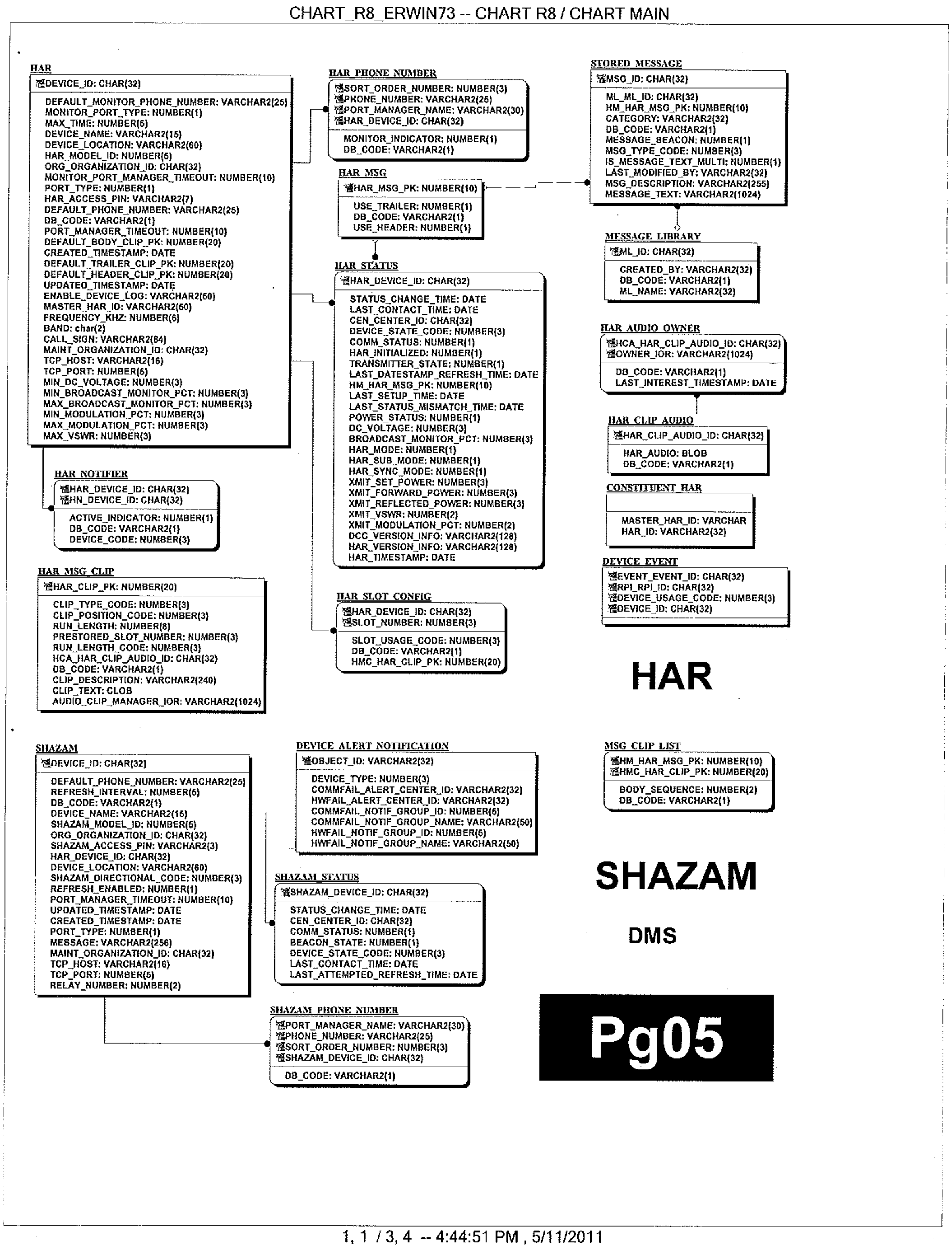
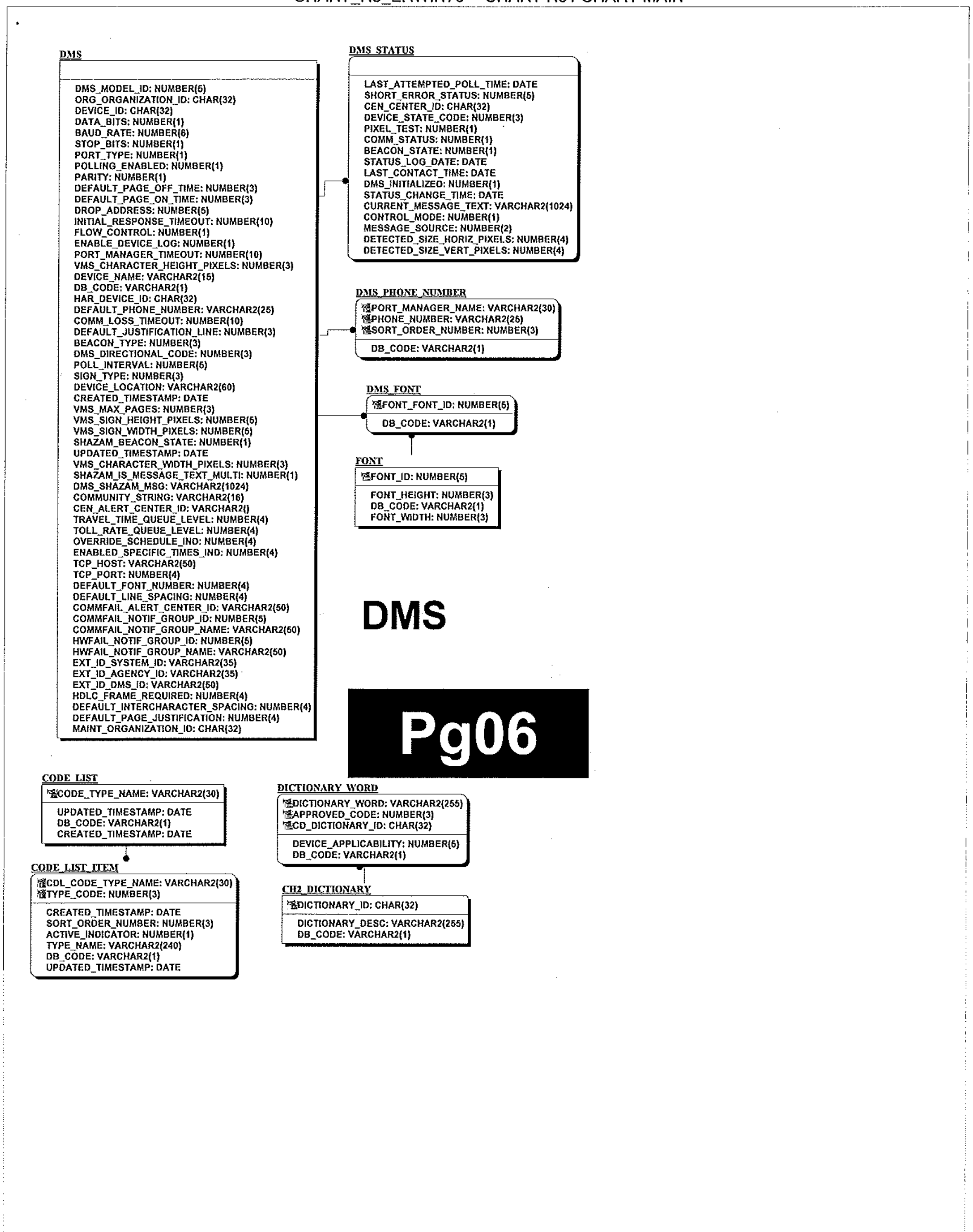


Figure 3-7. CHART ERD (5 of 14)

CHART_R8_ERWIN73 -- CHART R8 / CHART MAIN



1, 2 / 3, 4 -- 4:44:51 PM , 5/11/2011

Figure 3-8. CHART ERD (6 of 14)

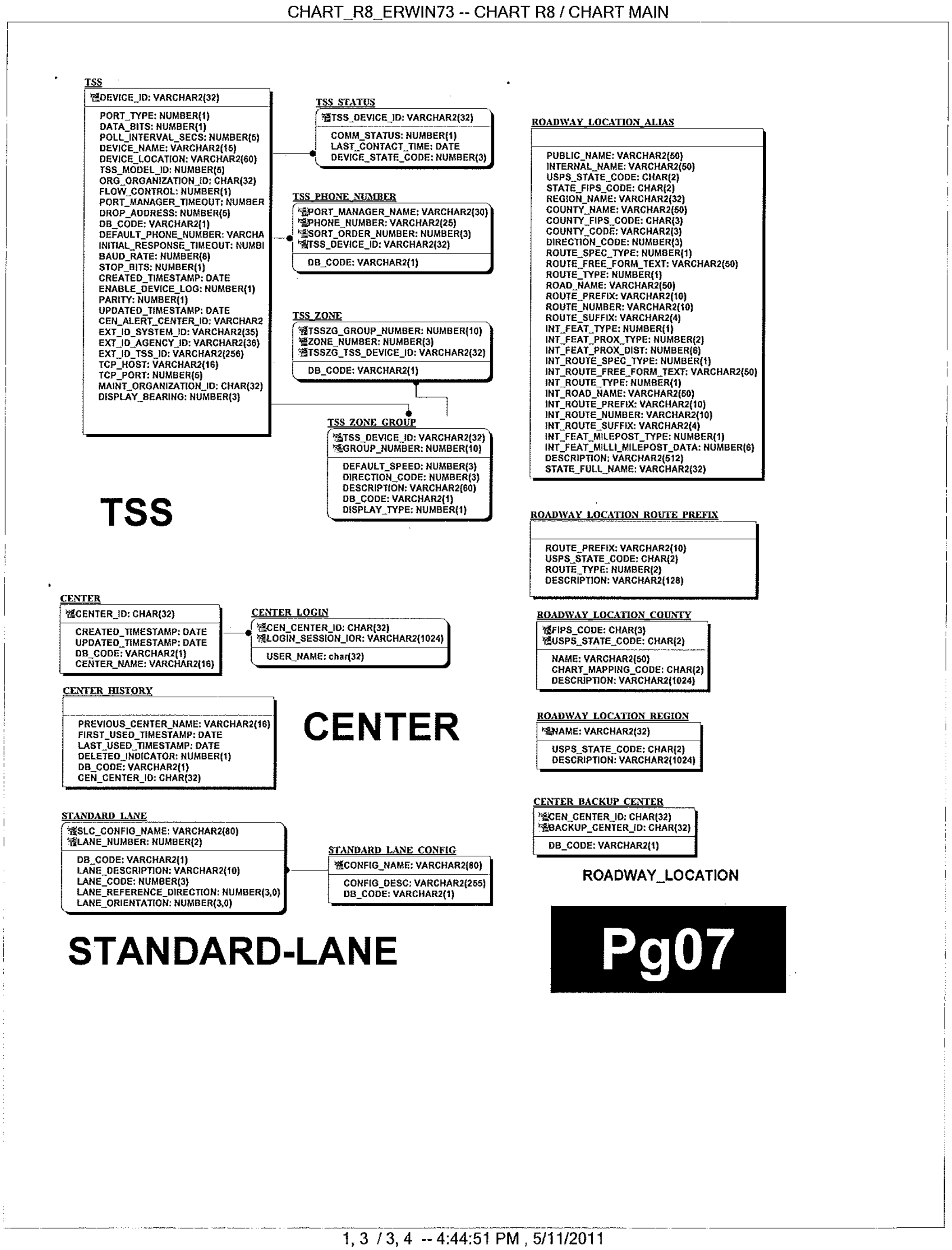


Figure 3-9. CHART ERD (7 of 14)

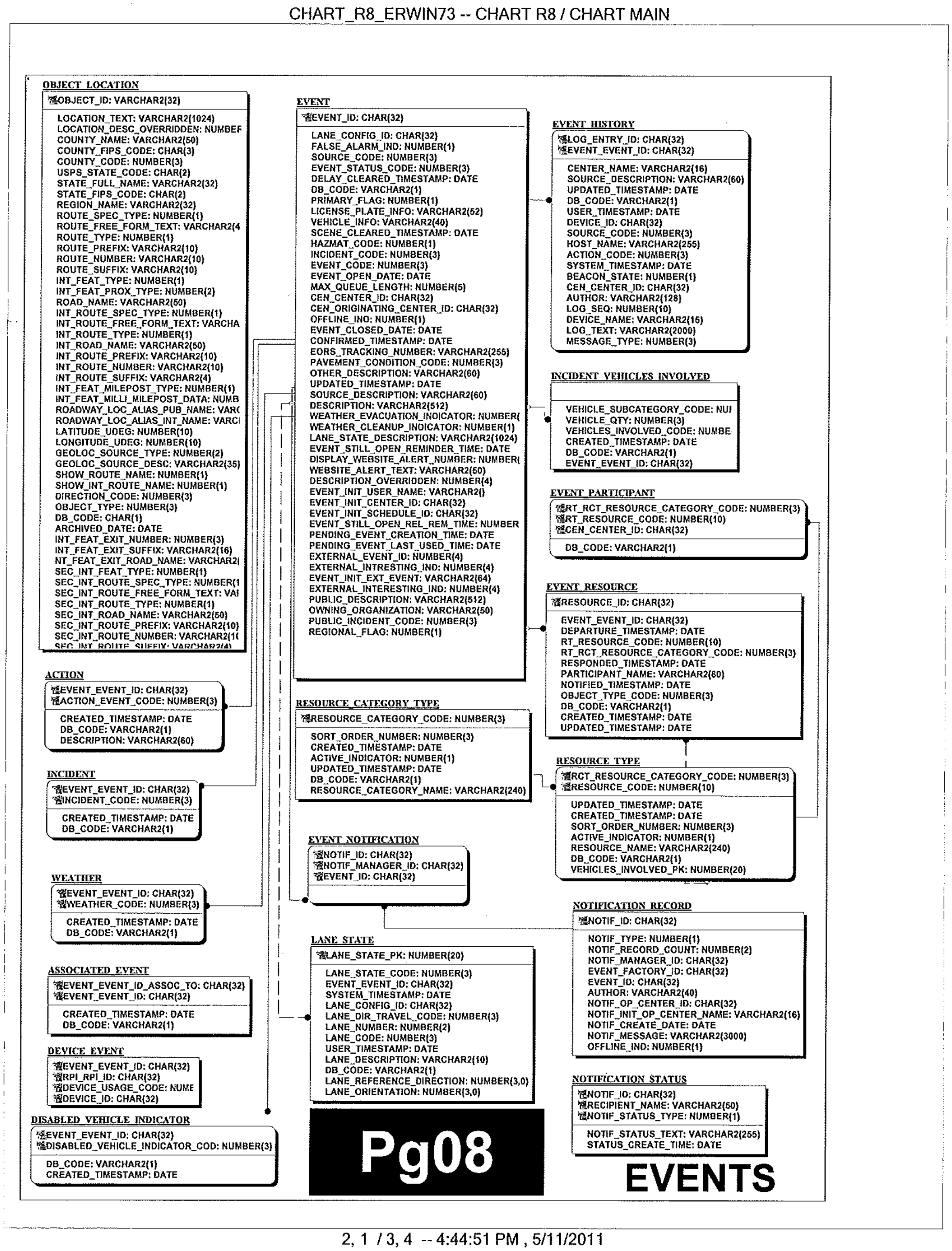


Figure 3-10. CHART ERD (8 of 14)

CHART_R8_ERWIN73 -- CHART R8 / CHART MAIN

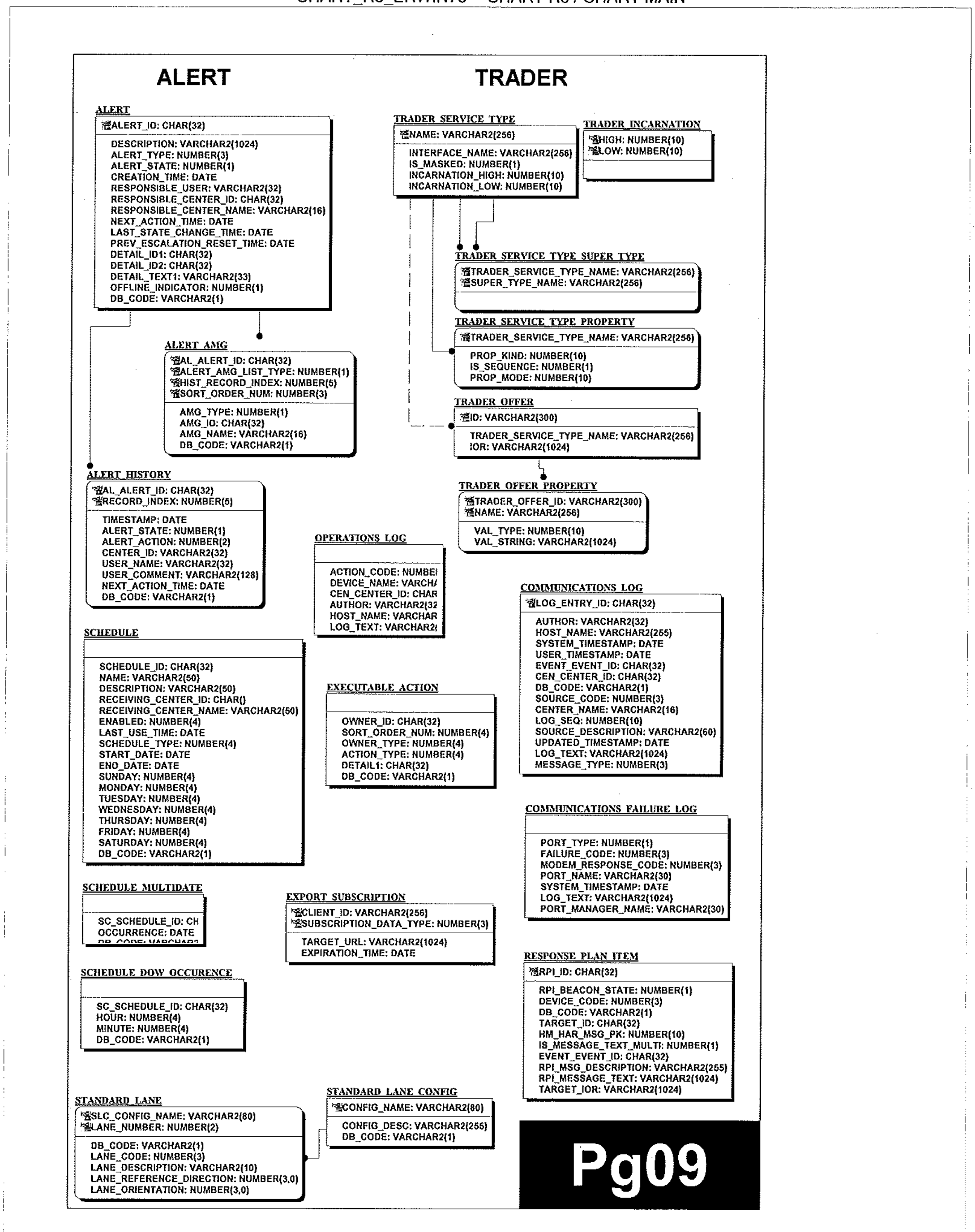


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Figure 3-11. CHART ERD (9 of 14)

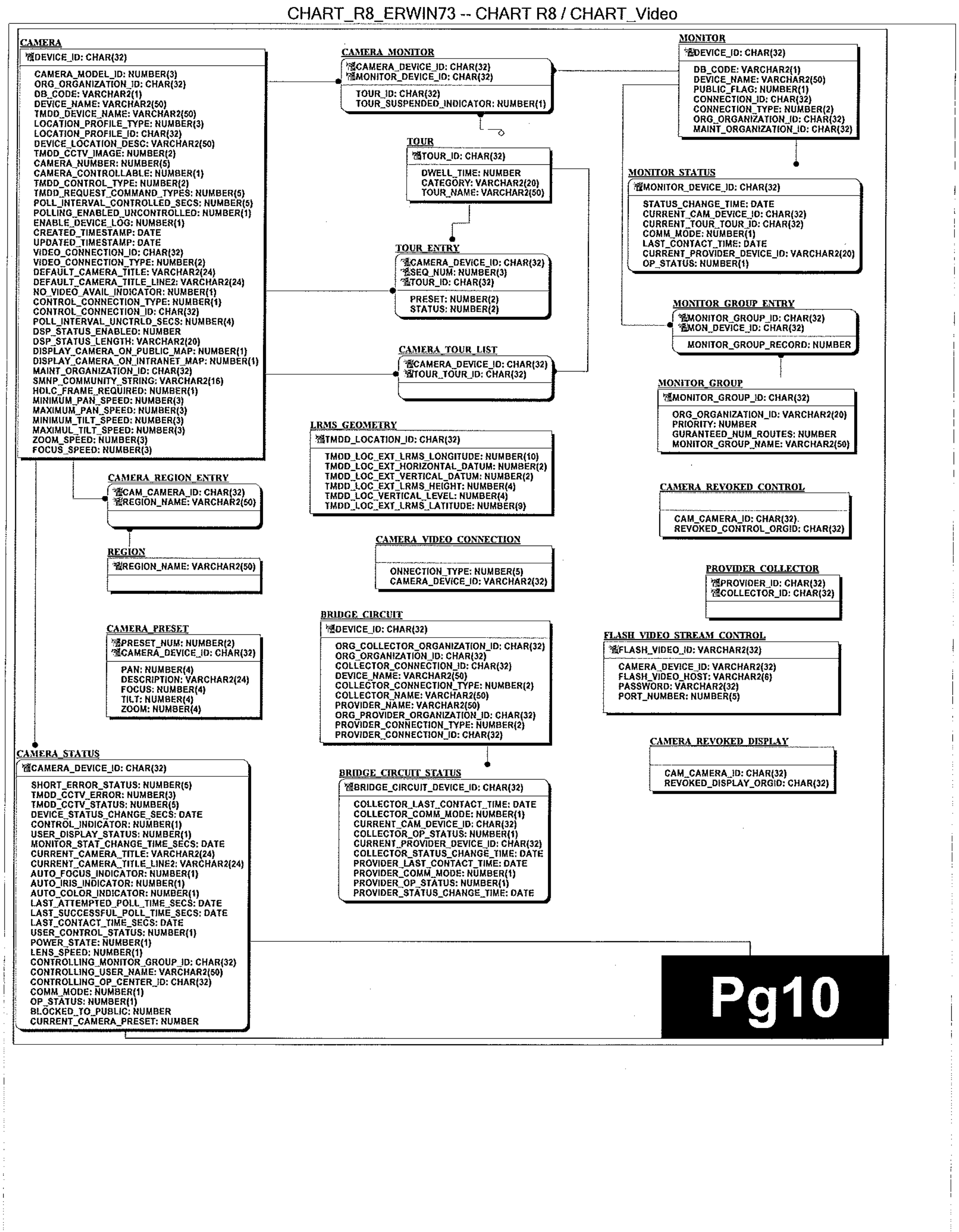

Figure 3-12. CHART ERD (10 of 14)

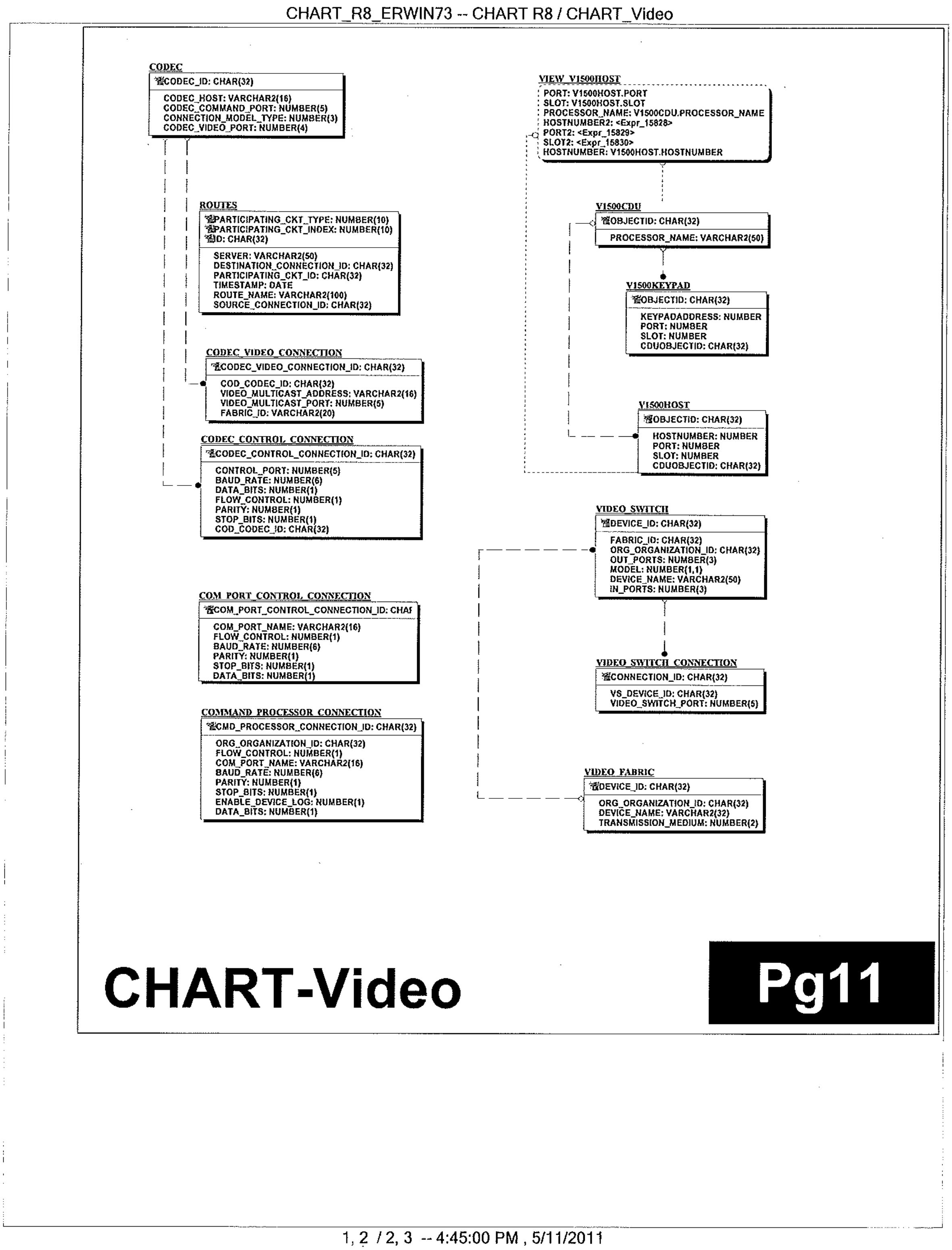

Figure 3-13. CHART ERD (11 of 14)

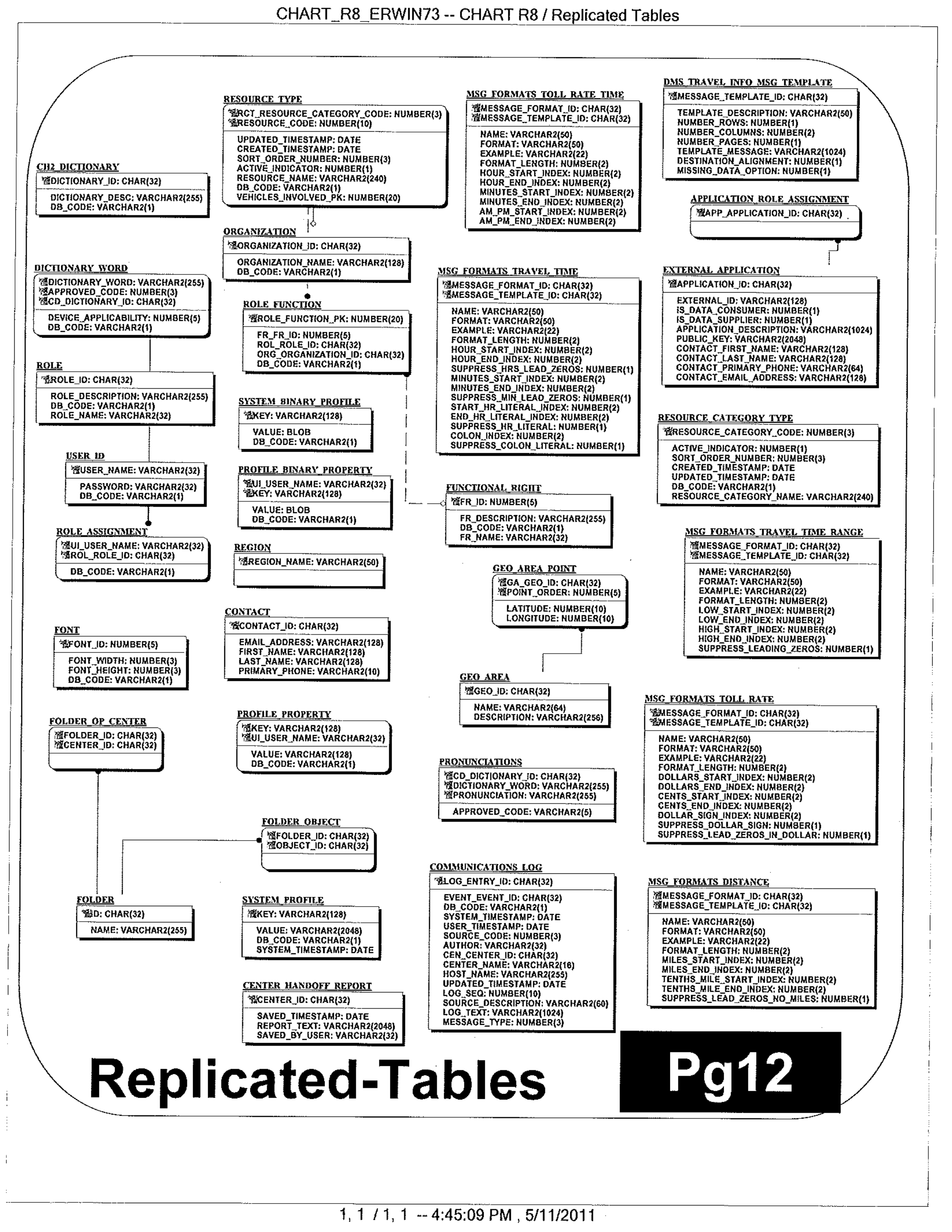

Figure 3-14. CHART ERD (12 of 14)

CHART_R8_ERWIN73 -- CHART R8 / Travell Route and Toll Rate

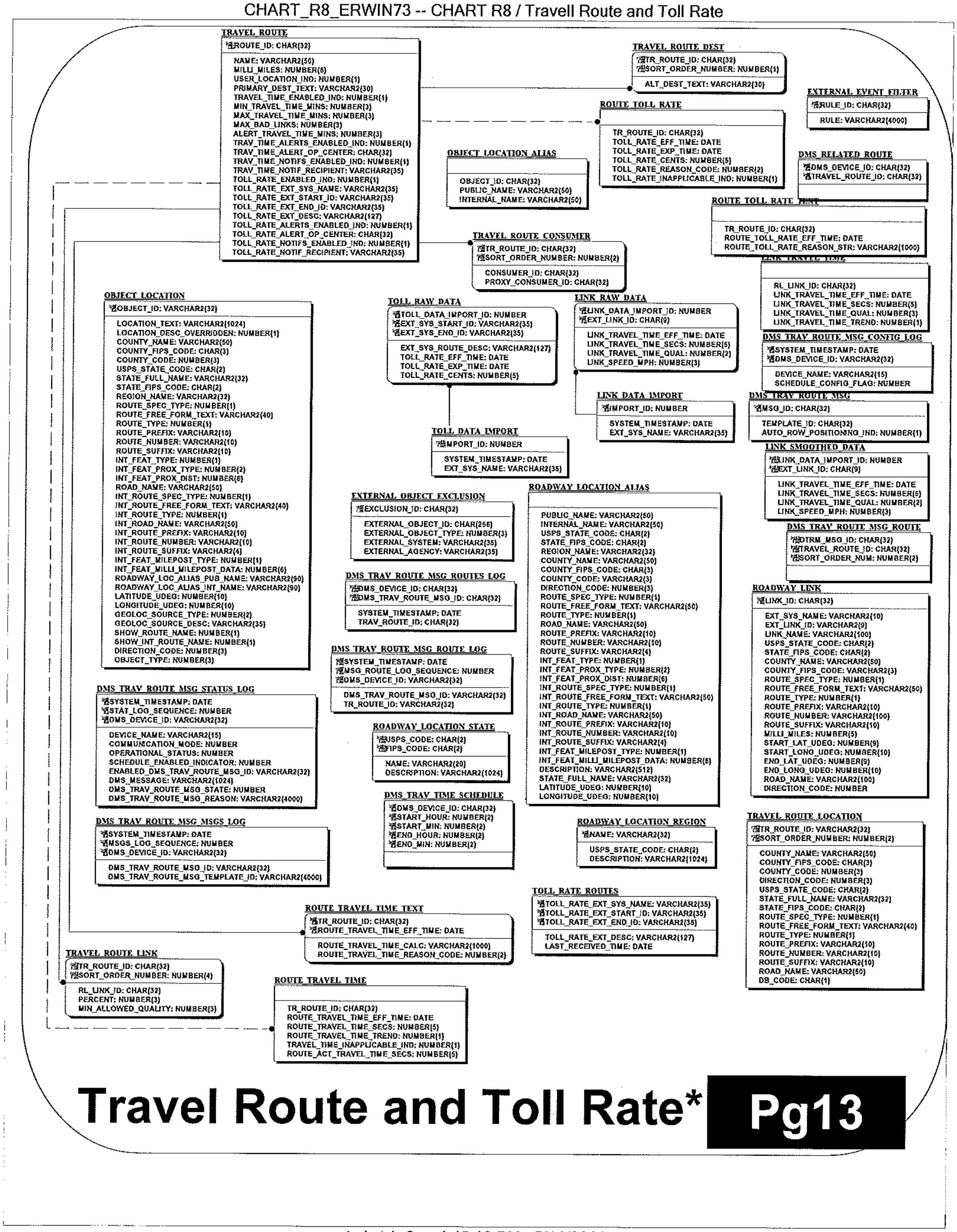

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Figure 3-15. CHART ERD (13 of 14)

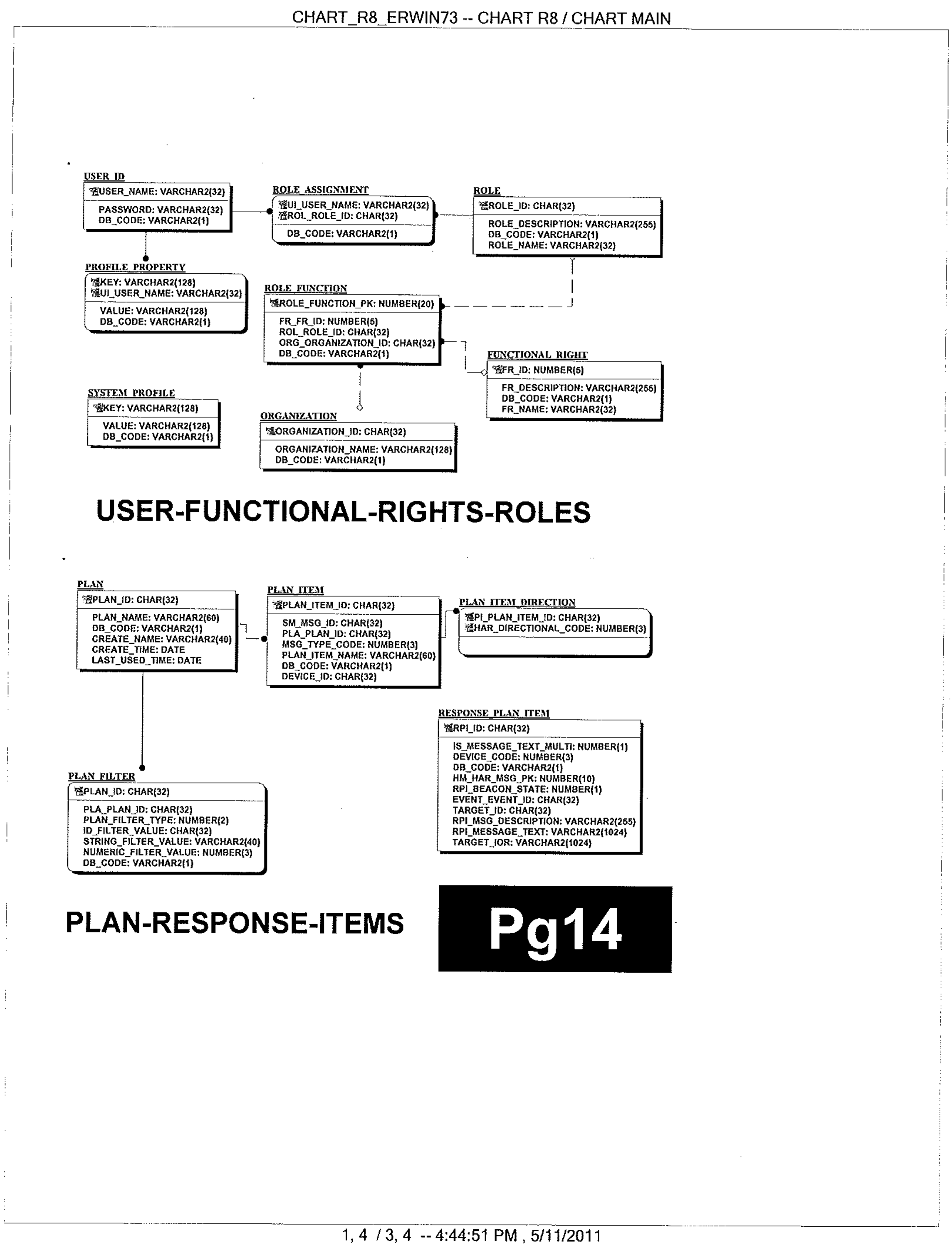


Figure 3-16. CHART ERD (14 of 14)

3.2.5.1 User/System Management

The user/system management entities consist of the complete suite of information to tie together the users, roles, organizations, and functional rights with the center's identification. The user/system management entities are considered static data in the sense that the majority of the data will be pre-loaded either through a GUI or via SQL loads.

3.2.5.2 Device Configuration

The DMS, HAR, SHAZAM, TSS, Camera, Monitor, and other CCTV video entities include data that define the configuration of the resources for devices. Each device or detector is associated with an organization via a foreign key. The organization is responsible for all devices and for each model type to which it is related.

All device configuration data is maintained by the CHART database and is supplied to the FMS as part of a service request. However, configuration data for devices related to video distribution is not supplied to the FMS, since CCTV camera communications do not use the FMS.

Operationally, all of the device configuration data is considered static data. While this data is changeable to reflect configuration changes at the field sites, these changes occur infrequently.

3.2.5.3 Device Status

The DMS, HAR, SHAZAM, TSS, Camera, and Monitor entities include data that define the status or state of the devices. Some status information (e.g. last poll time, last polled detector speed data) changes very frequently. Other status information (e.g., the message on a DMS) changes less frequently.

3.2.5.4 Traffic Event Response Planning

The planning entity consists of all of the data necessary for an operator to execute a response plan from within an open traffic event. Response plans include preselected HAR and DMS devices with messages related to a well known event such as recurring congestion at a particular location.

This data is considered to be fairly static, although libraries and plans are easily updated. These data set up the plan scenario for a given event. It is used manually by operators to refine the plan or create their own.

The dictionary entity data assists the operator by checking spelling and checking for banned words when creating messages for the message library, for DMS messages, and for HAR text message clips, and by doing pronunciation substitution prior to text to speech for HAR text message clips.

3.2.5.5 Events and Logging

The events entity includes all informational data related to traffic incidents. It also includes any devices that are part of the response to an event, such as DMSs and HARs. Also included are various log data that are described in more detail below.

The logs that are maintained are listed below:

- Communications Log
- Event Log
- Operations Log

The Communications Log entity documents operator communications, and may or may not be tied to a specific traffic event. The event log contains operator and system generated entries specific to actions associated with a particular traffic event. The Operations Log entity stores all system generated events, including device usage and component failures.

3.2.5.6 Alerts

The alerts entity includes all informational data related to alerts. Alerts are dynamic data. Most alerts are created by the system automatically, although manually generated generic alerts are also supported. Alert status and history data can be updated frequently. All alert data is archived.

3.2.5.7 Notification

The notification entity includes all informational data related to notifications. Notifications are dynamic data. Notification status data are updated frequently.

3.2.5.8 Schedules

The schedules entity includes all informational data related to schedules. Schedules are fixed data. Users add schedules to the system and delete them when they are done. Schedules do not have dynamic status or history data.

3.2.5.9 System Parameters

The System Profile parameters are used for general CHART system operations. Examples of system parameters include:

- Days to purge operation log
- Which event types may be combined
- Which event types are comparable for event location duplication
- HAR date stamp format
- Alert system configuration parameters
- General GUI parameters

3.2.5.10 Travel Routes

The travel routes entity includes all informational data related to travel routes, used to provide travel time and/or toll rate data for use in traveler information messages. Travel routes are fixed data. Administrators add travel routes to the system in preparation for displaying travel times or toll rates on DMSs. Travel routes do not have dynamic status or history data.

3.2.5.11 Replication

The database will provide replication of all entities required for a CHART server site to run independent of any other CHART server site, as might occur with a network outage between sites. This includes data related to CHART GUI (profile, folders), user management (including external client IDs and public keys), and dictionary data. The data related to logging and resources is replicated as well.

Device configuration data is not replicated since each device is homed to only one server. Other CHART servers access that device configuration through the appropriate CORBA Trading

Service. Similarly, traffic event information, alerts information, notification information, and schedule information are homed to only one server and therefore not replicated.

3.2.5.12 Archiving

The CHART Archive database stores data from the CHART operational system as part of a permanent archive. The CHART Archive database design is a copy of the CHART operational system for those tables containing system, alert, and event log information. In addition, the CHART Archive database stores detector data. This data is stored as time annotated averages at selected frequencies. See Figure 2-6 which includes the ERD for the Archive database.

3.3 Hardware CIs

This section presents the hardware CIs that make up the CHART system. Each hardware CI is described and a list of major components is provided.

3.3.1 CHART Application Server Description

The CHART application server system supports the CHART software CIs. This system consists of a server along with associated storage array and network connection devices. These systems are currently deployed in a virtual environment at the SOC with a backup capability at SHA headquarters.

The CHART application server system configurations are:

CHART Application server – all but SOC

- 4 vCPUs 2.666 GHz Intel XEON CPU or equivalent
- 6 GB Total SDRAM
- 20 GB D: drive, 120 GB D: drive, 120 GB E: drive
- Internal CD-ROM Drive
- Gigabit NIC card

CHART Application server - SOC

- 8vCPUs 2.666 GHz Intel XEON CPU or equivalent
- 16 GB Total SDRAM
- 50 GB C: drive, 300 GB D: drive, 4 TB E: drive (for DB backup, archive DB)
- Internal CD-ROM Drive
- Gigabit NIC card

The nominal CHART server system software configuration is shown in the table below. Under normal conditions the primary server executes all CHART software subsystems. In a fail-over situation the failover virtual environment would support all CHART software subsystems. The required COTS packages to support CHART are installed on each server.

Table 3-4. CHART Server Software

CHART Application Server Software CIs
CHART: Alert Management Audio AVL (future) Communications Log Management Data Export Management Data Import Management Device Management Dictionary DMS Control HAR Control HAR Notification Message Library Management Notification Management Plan Management Resource Management Schedule Management Signals (future) Simulation (future) System Monitor Traffic Event Management Traveler Information Management User Manager Utility
COTS: JRE Microsoft VC++ Nuance text To Speech Oracle ORB Trader Windows 2003 Server

3.3.2 CHART GUI Web Server Description

The CHART GUI Web servers are currently deployed in a virtual environment at the SOC with a backup capability at SHA headquarters. The configuration of each CHART GUI Web server will be similar to the following:

- 4 vCPUs 2.666 GHz Intel Xeon or equivalent
- 3 GB SDRAM
- 20 GB C: drive, 50 GB D: drive
- Gigabit NIC card

3.3.3 FMS Description

In order to provide for reduced recurring telecommunications costs, the FMS servers are located in environmentally-controlled facilities (e.g., Closed Circuit Television [CCTV] vaults) within the same or an adjoining Verizon Central Office (CO) service region as the devices with which they normally communicate. In addition, communications between the FMS server and the field devices is provided via Integrated Services Digital Network (ISDN) Centrex service or local POTS. In this manner, any number of calls may be placed between the FMS server and the field devices at a fixed monthly recurring cost.

FMS server component communications are aggregated within a given Local Access Transport Area (LATA) via Verizon Frame Relay services to the local MDOT node. This data is then transported using the MDOT backbone to a CHART server site. This use of the MDOT backbone minimizes recurring telecommunications costs for the CHART program.

The existing FMS server components were developed for, and tested and fielded on, the following hardware platforms:

FMS Server – ISDN :

- Dual Intel Pentium^{R} 4 3.0 GHz processor or equivalent
- 1 GB SDRAM memory
- 2 PCI, and one PCI/ISA
- 80 GB hard drive
- Gigabit NIC card
- Hot Plug Redundant Power Supply

FMS Server – ISDN, POTS, Telephony:

- Dual Intel Pentium^{R} 3 1.26 GHz processor
- 3.0 GB SDRAM memory
- 3 PCI, and one PCI/ISA
- 18 GB hard drive
- Hot Plug Redundant Power Supply
- Gigabit NIC card

Network communications are provided via the embedded Compaq 10/100 TX PCI UTP Controller on the CPU motherboard. ISDN communications are supported through the use of Dialogic Diva Server ISDN boards. Communications over POTS are supported by Digi International RAS-8 boards. Finally, Dialogic Springware D4PCI-U boards are used to provide the telephony functionality.

As noted before, ISDN-based communications are being phased out in favor of wireless Ethernet services. This will result in the decommissioning of most of the FMS servers. Eventually, only the FMS servers at the SOC, AOC, and Greenbelt District 3 Headquarters equipped for POTS and telephony services will remain operational.

3.3.4 CHART Archive Server

The CHART Archive Server supports the archival of all CHART traffic event management, detector, and operational data and hosts the CHART Archive software subsystems. The system accepts queries and report requests from CHART operations personnel and external archive users. This system may also support applications for the analysis of traffic event and detector data (e.g. simulation applications and statistical analysis packages).

CHART Archive (Currently resides on SOC application server)

- 8vCPUs 2.666 GHz Intel XEON CPU or equivalent
- 16 GB Total SDRAM
- 50 GB C: drive, 300 GB D: drive, 4 TB E: drive (for DB backup, archive DB)
- Internal CD-ROM Drive
- Gigabit NIC card

3.3.5 CHART Data Exporter Server

The CHART Data Exporter Archive Server supports the export of all CHART traffic event management, detector, DMS, HAR, and SHAZAM operational data to “external” entities (e.g., RITIS). The CHART Data exporter is will reside on the DMZ in the SOC and will have a minimum configuration equivalent to:

- Intel® Xeon™ Quad 2.4 GHz Processor or equivalent
- 3 GB SDRAM
- 20 GB C: drive, 50 GB D: drive
- Gigabit NIC card

3.3.6 AVL Server Description (future)

The AVL Server hardware will support the AVL server software and communications with AVL remote installations. The selection of this hardware will depend on the outcome of the AVL pilot project. For planning purposes hardware equivalent to an FMS server is assumed.

3.3.7 AVL Remote Description (future)

The AVL Remote hardware would be installed in CHART vehicles and on selected pieces of CHART equipment (such as portable DMS). There are two types of AVL Remote installations. The first supports location and status reporting, and two-way communications between CHART operations personnel and CHART vehicles. The second is for location and status reporting purposes only.

The detailed requirements for AVL installations will have to wait for the conclusion of the AVL pilot program.

3.4 High Availability

The CHART system design provides high availability through these methods.

- Distribution of equipment and functions.
- Replication of data.
- Redundancy within virtual environment and of communications paths.
- Offsite backup capabilities for the entire virtual environment

Each of these methods will be discussed in more detail below.

3.4.1 Distribution

The CHART system had been designed as a distributed system. Currently there are five "nodes" deployed on a single virtual environment located at the SOC. Functions are distributed onto the CHART nodes as needed. However, if a particular server needs only a subset of CHART functionality, services or modules would be configured not to run. For instance, if functionality such as Text to Speech is licensed on a per-server basis, there could be a costs savings at minimal impact to the system by reducing the number of Text to Speech Control Modules. These packaging options provide a great deal of flexibility in the configuration of the CHART servers.

FMS servers are likewise are distributed and are located so as to minimize low speed communications costs.

The distribution of components and functions enhances the availability of the overall system by preventing the loss of a single node from taking out the entire system. The advantages of distribution are further enhanced by the replication of data.

In the future, a virtualization and backup technologies have matured, the CHART system will be deployed on a single node in the SOC virtual environment.

3.4.2 Replication

The replication of data between CHART server nodes provides the system with the capability for continued availability of certain functionality and state information in the event of a CHART server failure. Future work along these lines could provide for replication of additional information, such as relatively static device configuration, message library, and plan data, and perhaps more dynamic device status, device queue and event log data, which would provide each server node with additional information required to provide further recovery of functionality in the event of a total failure at another node. Replication can be tuned on a per node basis such that those nodes that will not be providing backup services only receive the data required for normal operations such as user management and dictionary updates.

3.4.3 Redundancy

Redundancy is provided throughout the CHART system at several levels. In addition to the replication of data, redundant paths are provided for data access. By using RAID technology additional disks can be configured to keep disk volumes operational in the event of disk failure. Finally, the communications networks provide multiple paths for communications between CHART components.

Communications Paths

There are redundant or backup communications paths for communicating with field devices and supporting video and CHART Backbone network traffic.

The FMS servers provide communications services to CHART servers for the purpose of controlling and receiving data from traveler advisory devices and traffic monitoring devices. In the event of an FMS server failure one or more other FMS servers can provide backup for the failed server. This occurs transparently to the users of the system.

Virtual Environment

The CHART Virtual Infrastructure provides redundancy through the implementation of a cluster of hardware and software packages.

- Storage is provided by a multi-node iSCSI SAN cluster with redundant network connections accessible by all devices.
- A cluster of physical servers provides hosting to the virtual server environment, with the ability for two of the servers to take the load of the environment should one physical server suffer a total failure.
- Components within the blade infrastructure are arranged for redundancy. For example, one of the FLEX 10 networking modules could fail while connectivity would be maintained through the second module.
- The ability to "snapshot" a virtual server provides the ability to roll back a server to a previous state should an issue occur with that server, and simplifies maintenance and administration by allowing patches and upgrades to be applied without fear of server failure.

3.4.4 Offsite backup capabilities for the entire virtual environment

- Full image snapshots are taken nightly and copied to a co-location in Baltimore. Included in these snapshots are local snapshots with file and image-level restore functionality.
- The site at SHA HQ exists as a redundant and disaster recovery capable location where individual pieces or the entire CHART system can exist if necessary.

3.5 Release Strategy

The CHART system will be deployed in a series of phased releases. The schedule for the releases is driven primarily by operational requirements. Release 1 provided the foundation on which future releases are based and was the first operational release. Subsequent releases added additional functions prioritized by CHART operations needs. Hardware resources were deployed in a phased manner to support each system release. A detailed schedule for each release broken down by release and build was provided in the original CHART System Development Schedule. A summary description of the system capabilities for each of the planned releases is presented in the following sections.

3.5.1 CHART Release 1

Release 1 provides system administration, DMS, HAR, and basic traffic management support. The Release 1 software capabilities are listed in Table 3-7. Release 1 was deployed with a dual server system in a local SAN located at the SOC. The text-to-speech conversion software was hosted on the backup server at the SOC and on an interim system located at the Greenbelt site. The Greenbelt TTS server can be any existing system with a processor speed of at least 400MHz. Multiple remote client systems were deployed as needed. Release 1 also included the deployment of a redesigned FMS server system. Figure 3-6 shows the server configuration at the Hanover, Greenbelt, and Brooklandville sites at the end of Release 1. Since CCTV video distribution had not yet been integrated with the CHART system, the existing video distribution system (AVCM) servers remained as separate components. This diagram is a high level view of the system and is meant to impart the architecture concepts. In the interest of keeping the diagram readable, every system component is not shown.

Table 3-5 CHART Release 1 Functions

CI	SUBSYSTEM	FUNCTIONALITY

CI	SUBSYSTEM	FUNCTIONALITY
CHART II	Audio	TTS conversion
	Communications Log Management	
	Device Management	Device online/offline/maintenance mode
	Dictionary	
	DMS Control	
	HAR Control	
	HAR Notification	
	Message Library Management	
	Plan Management	
	Resource Management	User login
	System Monitor	Logging system actions
	Traffic Event Management	Manual incident data entry Operator selection of incident response actions EORS (initial interface)
	User Manager	Roles and functional rights
	Utility	CHART Chat
	All	Navigator GUI
FMS	Port Manager	ISDN, POTS
	Protocol Handlers	DMS, HAR, SHAZAM
CHART Archive	Data Management	Interim storage for archive data

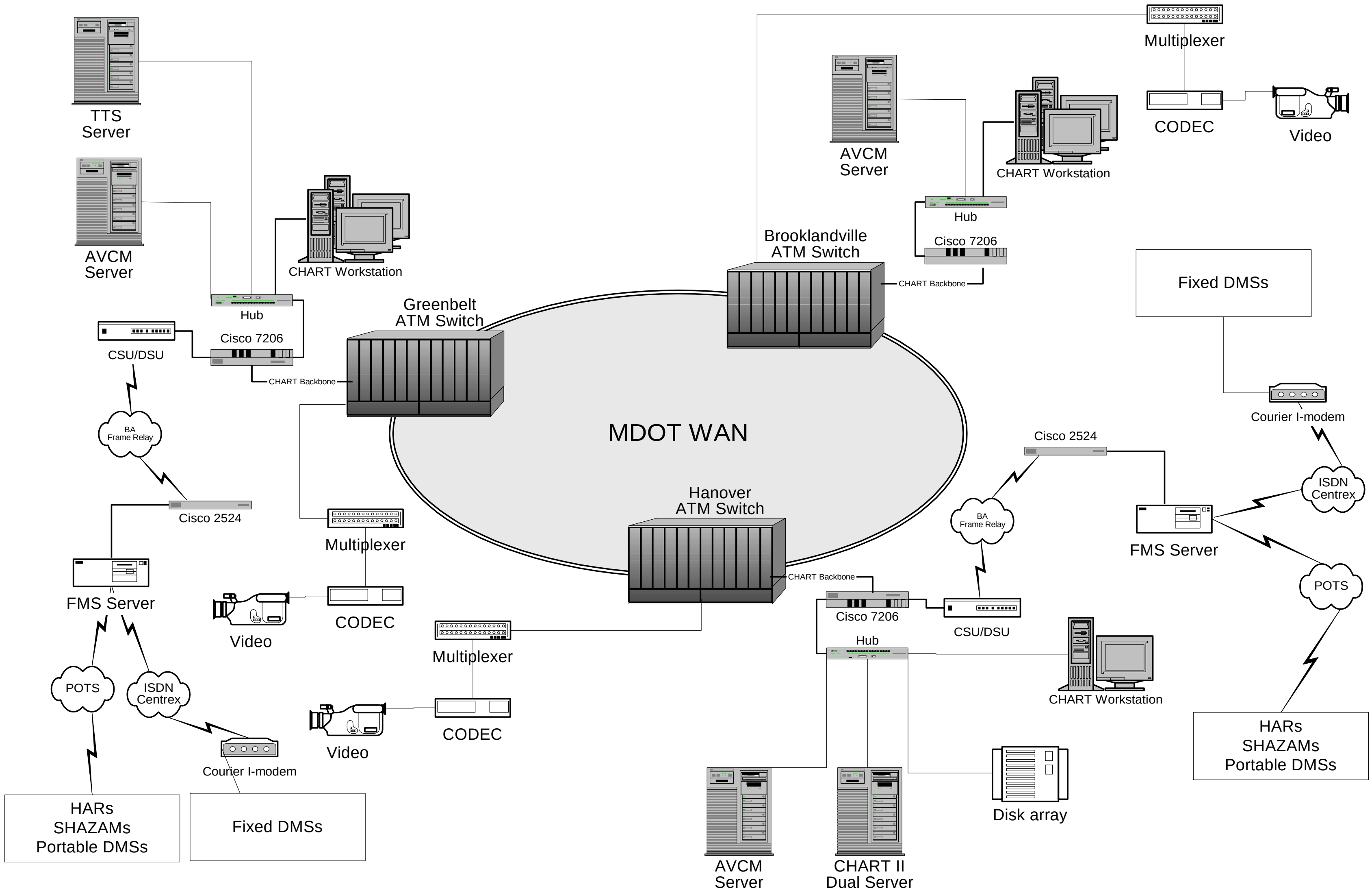


Figure 3-17. CHART Release 1 Server Installations

3.5.2 CHART Release 2

Release 2 provided video integration into CHART, un-federation of the CHART servers, disabling the “thick” Java-based CHART GUI, the addition of direct connect communications ports for low speed data communications (see Table 3-8), and support for a new CORBA ORB (JacORB). This release worked exclusively with the CHARTLite browser based GUI. This release provided upgraded MdTA integration capabilities. Additionally, this release provided support for additional models of HARs for the CHART HAR subsystem. An updated CHART Reporting capability was released during this time period, however it was considered independent of CHART Release 2. Figure 3-7 is a high level view of the system and is meant to impart the architecture concepts of this release. In the interest of keeping the diagram readable, every system component is not shown.

Table 3-6 CHART Release 2 Functions

CI	Subsystem	FUNCTIONALITY
CHART	Video Management	Camera Display
		Camera Control
	FMS	HAR Subsystem
	FMS	Direct Port Communications
CHART Archive	Data Management	CHART operational data Detector data
	Report Generator	Operational reports

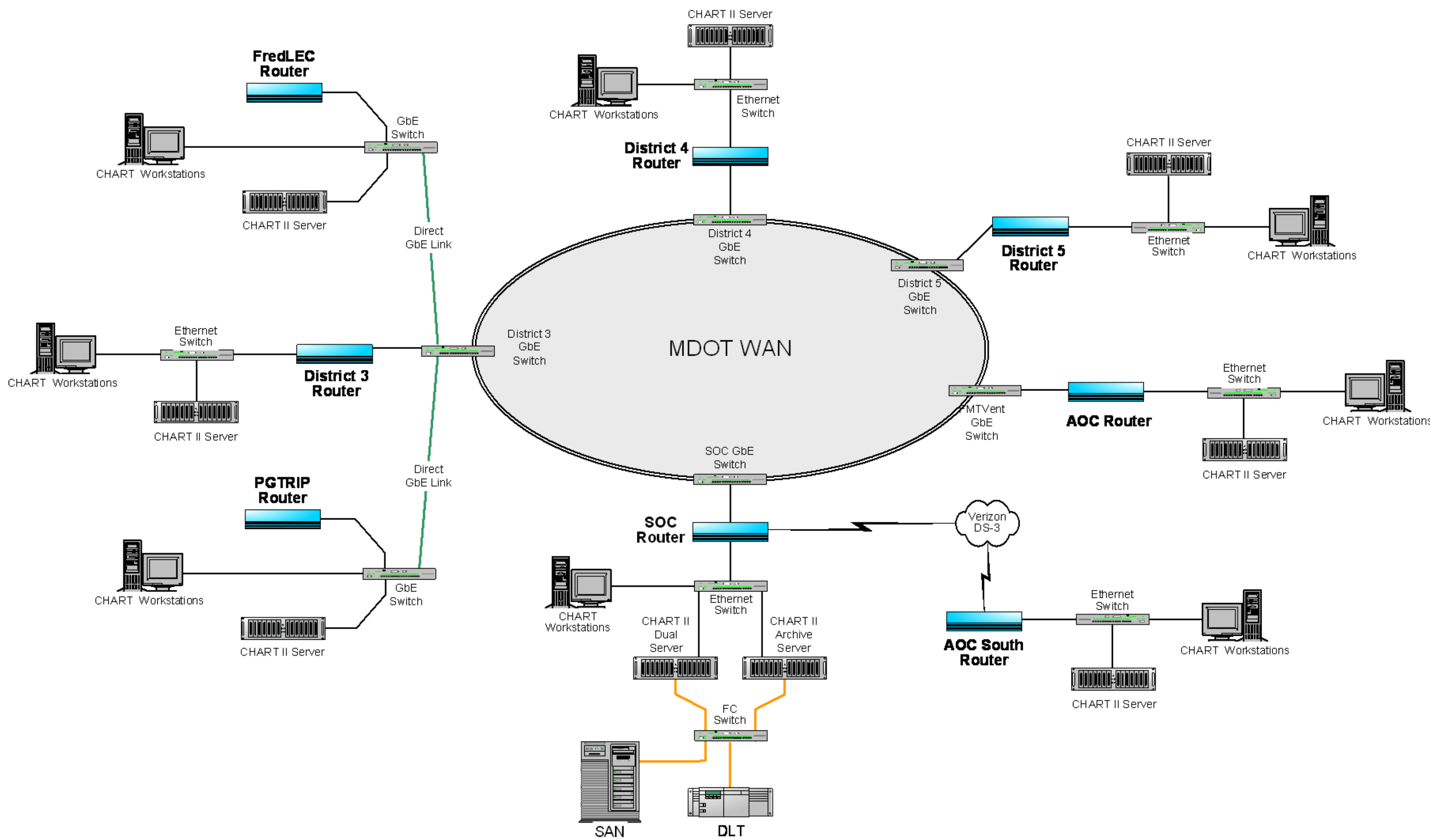


Figure 3-18. CHART Release 2 Server Installations

3.5.3 CHART Release 3

Release 3 added a newly designed CHART GUI , alert support, schedule support, notification support, additional incident management capabilities, operational reports, data import capabilities from external systems (see Table 3-8), and support for automated Travel Times and Toll Rates on DMSs. It also provides geo-location capabilities for devices and traffic events. It also continues to enhance the traffic management capabilities. This release updates the CHART Archive interface with general reporting and predefined query capabilities.

Table 3-7 CHART Release 3 Functions

CI	Subsystem	FUNCTIONALITY
CHART	Alert	Escalation rules, alerts
	Data Import Management	CHART RITIS interfaces
	DMS	TCP/IP communications, automated Travel Times and Toll Rates
	Notification Management	page, email
	Traffic Event Management	Advanced management Improved Lane graphic control geo-location
	Traveler Information Management	Travel times and toll rates for display in GUI and on DMSs
	TSS	TCP/IP communications support
	User Manager	Operations
	Utility	CHART Chat Map import Equipment inventory
	Device (Video, DMS, HAR, SHAZAM, TSS)	Geo-location of CHART devices

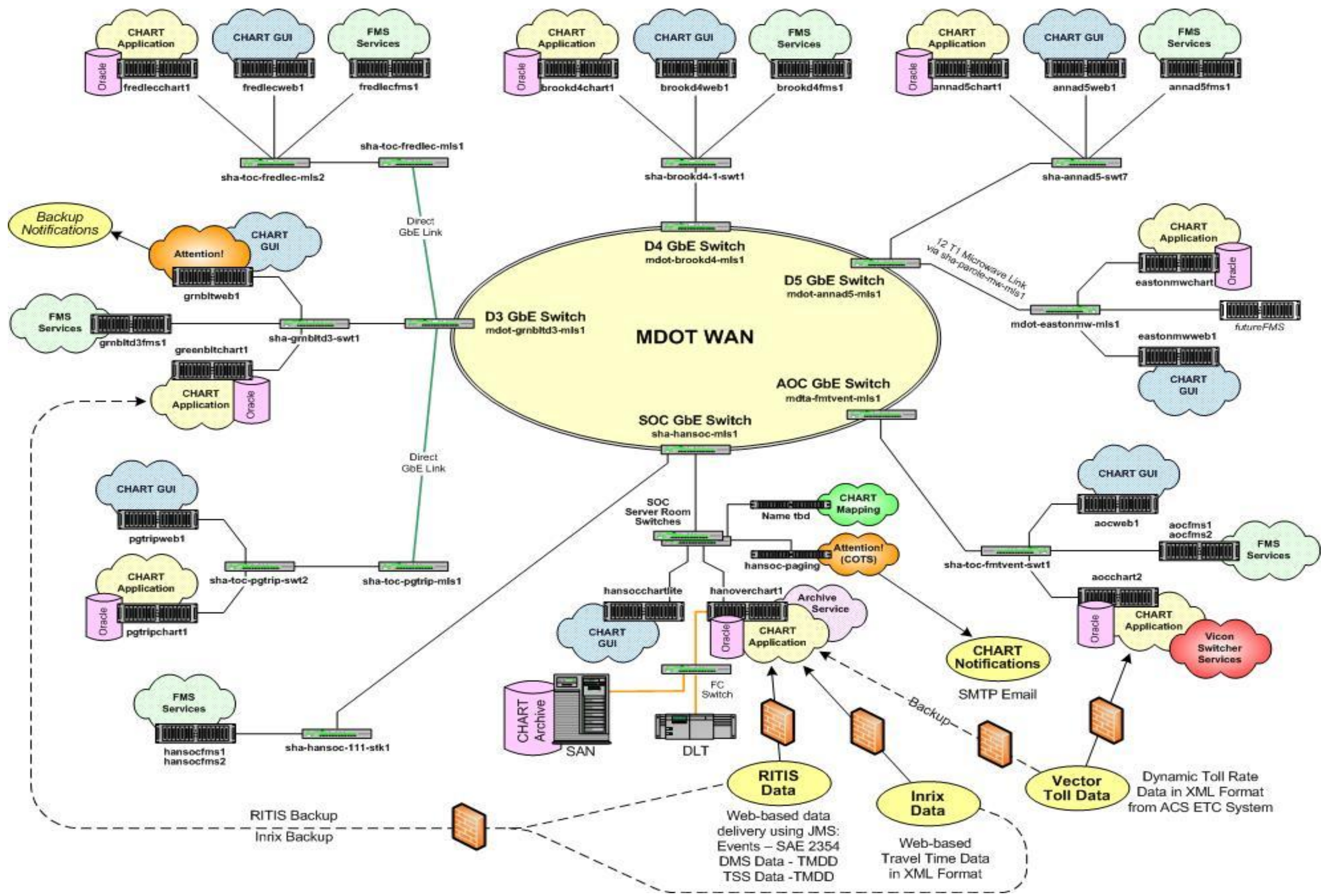


Figure 3-19 CHART Release 3 Server Installations

3.5.4 CHART Release 4

Release 4 added the System Monitor subsystem, via a new service known as the Watchdog. This new service is installed on every CHART server and FMS server and monitors the availability of each CHART service on the server where it is installed. A second Watchdog service on each server allows monitoring of the Watchdog services. The Watchdog provides the ability for alerts and notifications to be sent automatically when a service is detected to be failed, and provides for the ability to auto-restart services when failures are detected. Release 4 also added a new GUI portal known as the maintenance GUI, which provides a view of the system tailored to device maintenance personnel for use via laptops in the field. Release 4 included updates to the NTCIP DMS model to support version 2 of the protocol and to add several status fields and features. Lastly, Release 4 added an updated version of the middleware used by all CHART services to address stability issues.

Table 3-8 CHART Release 4 Functions

CI	Subsystem	FUNCTIONALITY
CHART	Alert	System Alert added.
	DMS	Updates to NTCIP DMS model to support version 2 and add functionality.
	GUI	Device Maintenance Portal added.
	System Monitor	Watchdog services added.

NOTE: There are no changes to the Server Installations for Release 4. See CHART Release 3 Server Installations above.

3.5.5 CHART Release 5

Release 5 added an integrated map, where users will be able to locate CHART devices and traffic events on a map. Release 5 also adds a Data Exporter feature – an interface into the CHART system to allow external systems to receive DMS, TSS, Traffic Event, HAR, and SHAZAM configuration and status information from CHART. Finally, CHART Release 5 provides some enhancements to video so that a camera can be configured with multiple video sending devices.

Table 3-9 CHART Release 5 Functions

CI	Subsystem	FUNCTIONALITY
CHART	Data Export Management	Export CHART data
	Device (Video, DMS, HAR, SHAZAM) and Traffic event Management	Map integration
	Video Management	Enhancements to Camera Display

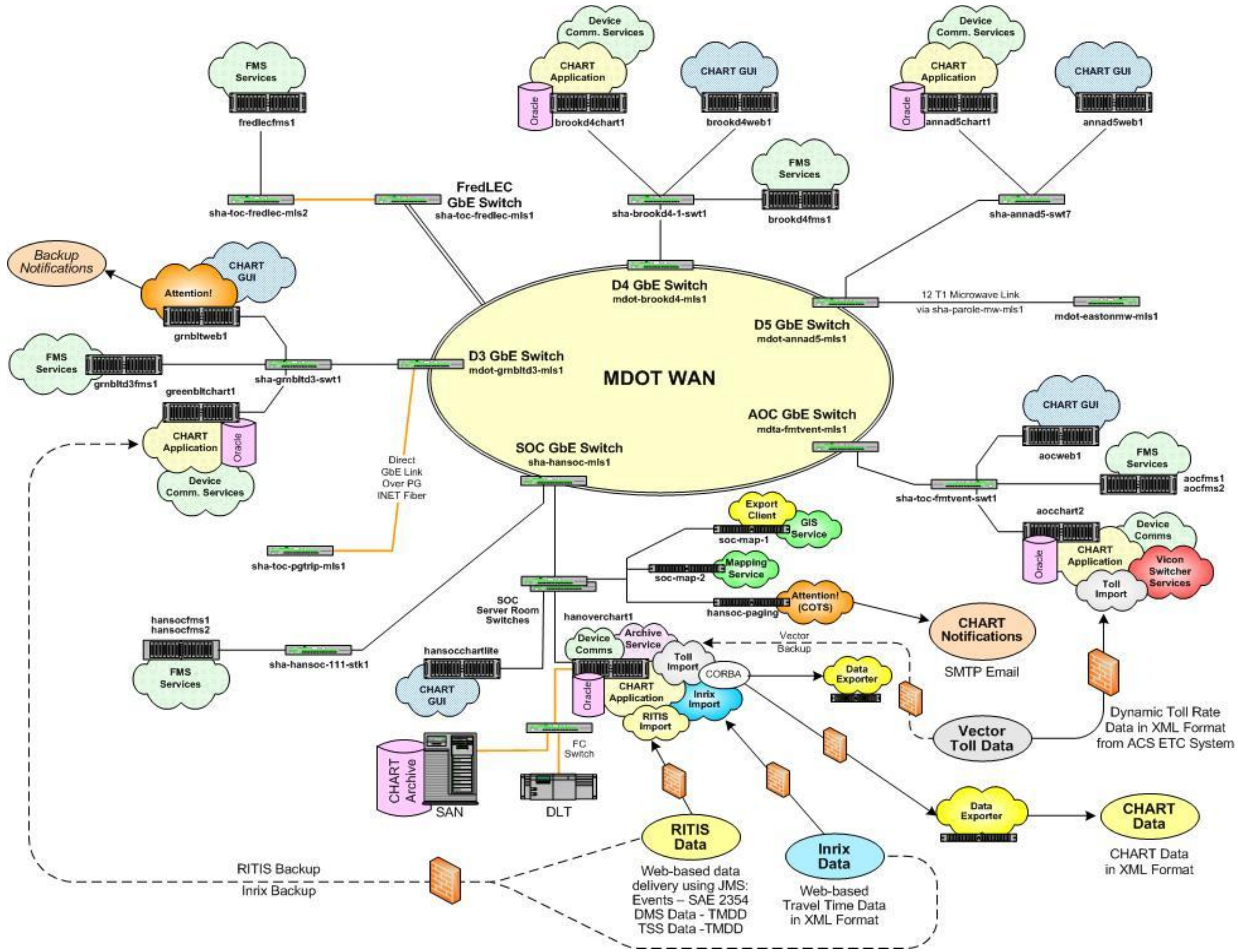


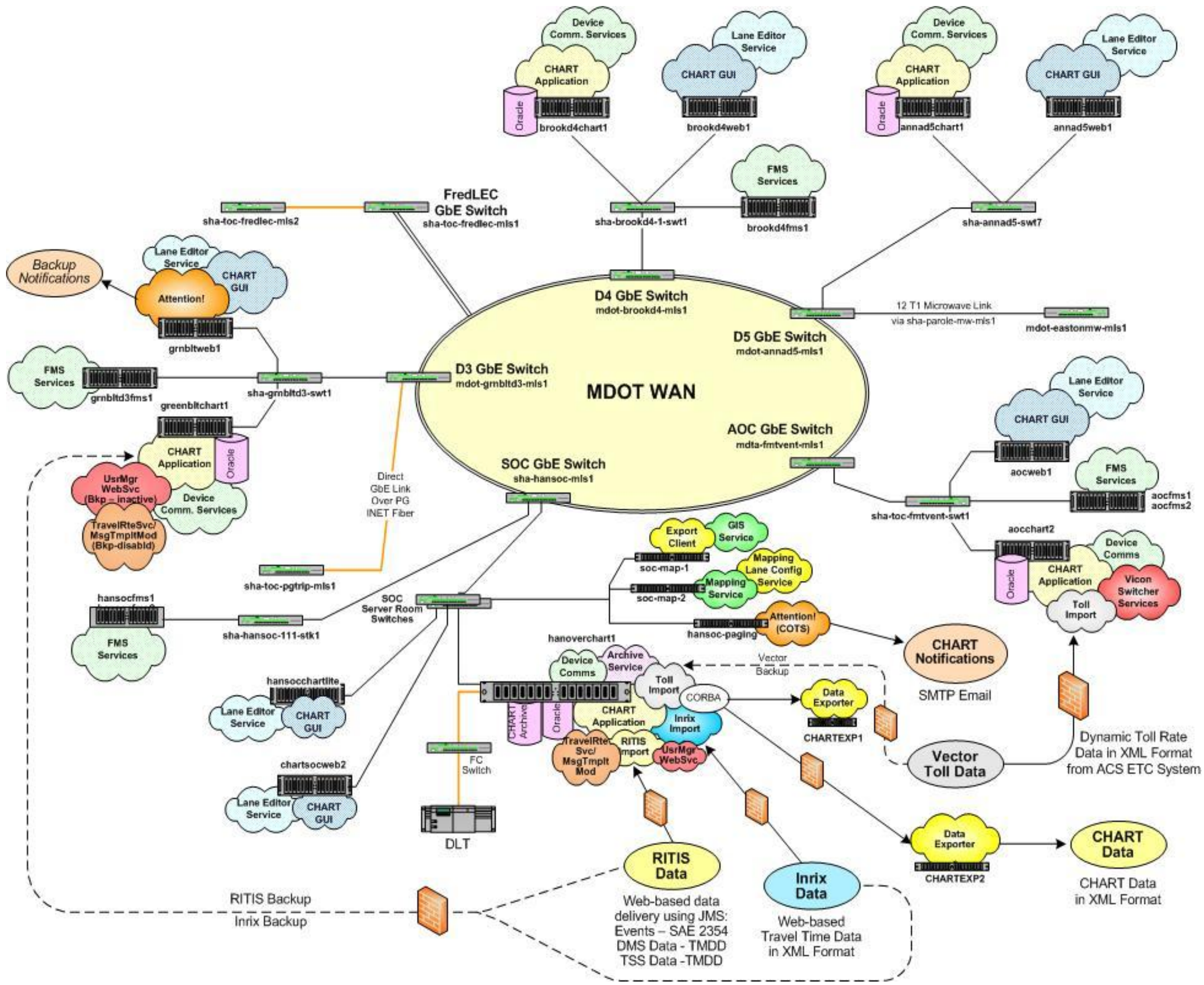
Figure 3-20 CHART Release 5 Server Installations

3.5.6 CHART Release 6

Release 6 added enhanced lane configuration capability, including suggested lane configurations based on the location of a traffic event and the ability for the user to edit lane configurations. Also in release 6 is the ability to specify event locations as being between two features or spanning a length of roadway from one location to another location. Another enhancement makes it easier for users to associate CHART planned closure events with an EORS permit. External detectors (received via RITIS rather than native to CHART) are exported from CHART and can be displayed on the CHART Map. As of Release 6, camera configuration data is now centralized in CHART (rather than requiring additional configuration within CHART Map).

Table 3-10 CHART Release 6 Functions

CI	Subsystem	FUNCTIONALITY
CHART	Data Export Management	Updated to export event "between" and "from/to" locations, CCTV configuration information, and "external" TSS status and configuration information..
	Data Import Management	Import of NavTeq detectors
	Device Management	Import of NavTeq detectors, centralized camera configuration data.
	GUI	Enhanced lane configuration, event "between" and "from/to" locations, enhanced planned closure event to EORS permit association, centralized camera configuration data.
	Traffic Event Management	Enhanced lane configuration
	User Management	New user manager web service to allow CHART Map to authenticate CHART users for access to NavTeq data.



MDOT WAN
D4 GbE Switch
mdot-brookd4-mls1
D5 GbE Switch
mdot-annad5-mls1
D3 GbE Switch
mdot-grnbltd3-mls1
AOC GbE Switch
mdta-fmtvent-mls1
SOC GbE Switch
sha-hansoc-mls1
FredLEC
GbE Switch
sha-toc-fredlec-mls1
sha-toc-fredlec-mls2
Device Comm. Services
Lane Editor Service
CHART Application
CHART GUI
Oracle
brookd4chart1
brookd4web1
annad5chart1
annad5web1
FMS Services
brookd4fms1
sha-brookd4-1-swt1
sha-annad5-swt7
12 T1 Microwave Link
via sha-parole-mw-mls1
mdot-eastonmw-mls1
Backup Notifications
Attention!
grnbltweb1
grnbltd3fms1
sha-grnbltd3-swt1
greenbltchart1
UsrMgr WebSvc (Bkp – inactive)
TravelRteSvc/ MsgTmpltMod (Bkp-disabld)
Direct GbE Link Over PG INET Fiber
sha-toc-pgtrip-mls1
aocweb1
aocfms1
aocfms2
sha-toc-fmtvent-swt1
aocchart2
Device Comms
Vicon Switcher Services
Toll Import
Export Client
GIS Service
soc-map-1
Mapping Lane Config Service
Mapping Service
soc-map-2
Attention! (COTS)
hansoc-paging
CHART Notifications
SMTP Email
hansocfms1
sha-hansoc-111-stk1
SOC Server Room Switches
hanoverchart1
Archive Service
Vector Backup
CORBA
Inrix Import
RITIS Import
UsrMgr WebSvc
TravelRte Svc/ MsgTmplt Mod
CHART Archive
Data Exporter
CHARTEXP1
CHARTEXP2
Vector Toll Data
Dynamic Toll Rate Data in XML Format from ACS ETC System
hansocchartlite
chartsocweb2
FC Switch
DLT
CHART Data
CHART Data in XML Format
RITIS Data
Web-based data delivery using JMS:
Events – SAE 2354
DMS Data - TMDD
TSS Data -TMDD
Inrix Data
Web-based Travel Time Data in XML Format
RITIS Backup
Inrix Backup

Figure 3-21 CHART Release 6 Server Installations

3.5.7 CHART Release 7

Release 7 added camera control based on the National Transportation Communications for ITS Protocol (NTCIP) for CCTV cameras, importation of SCAN weather data into CHART, an enhancement to the CHART Map to display TSS icons showing the directional orientation of the detectors, and a redesigned method for generating the Shift Hand-Off Reports utilizing WordPress.

Table 3-11 CHART Release 7 Functions

CI	Subsystem	FUNCTIONALITY
CHART	Device Management	Adds NTCIP-compliant CCTV camera control
	Traffic Event Management	Import of SCAN weather data into Traffic Events
	GUI and Data Export Management	Adds directionally-orientated TSS icons on the CHART Map and exports the orientation data
	Utility	Shift Hand-Off Report generation re-hosted to WordPress

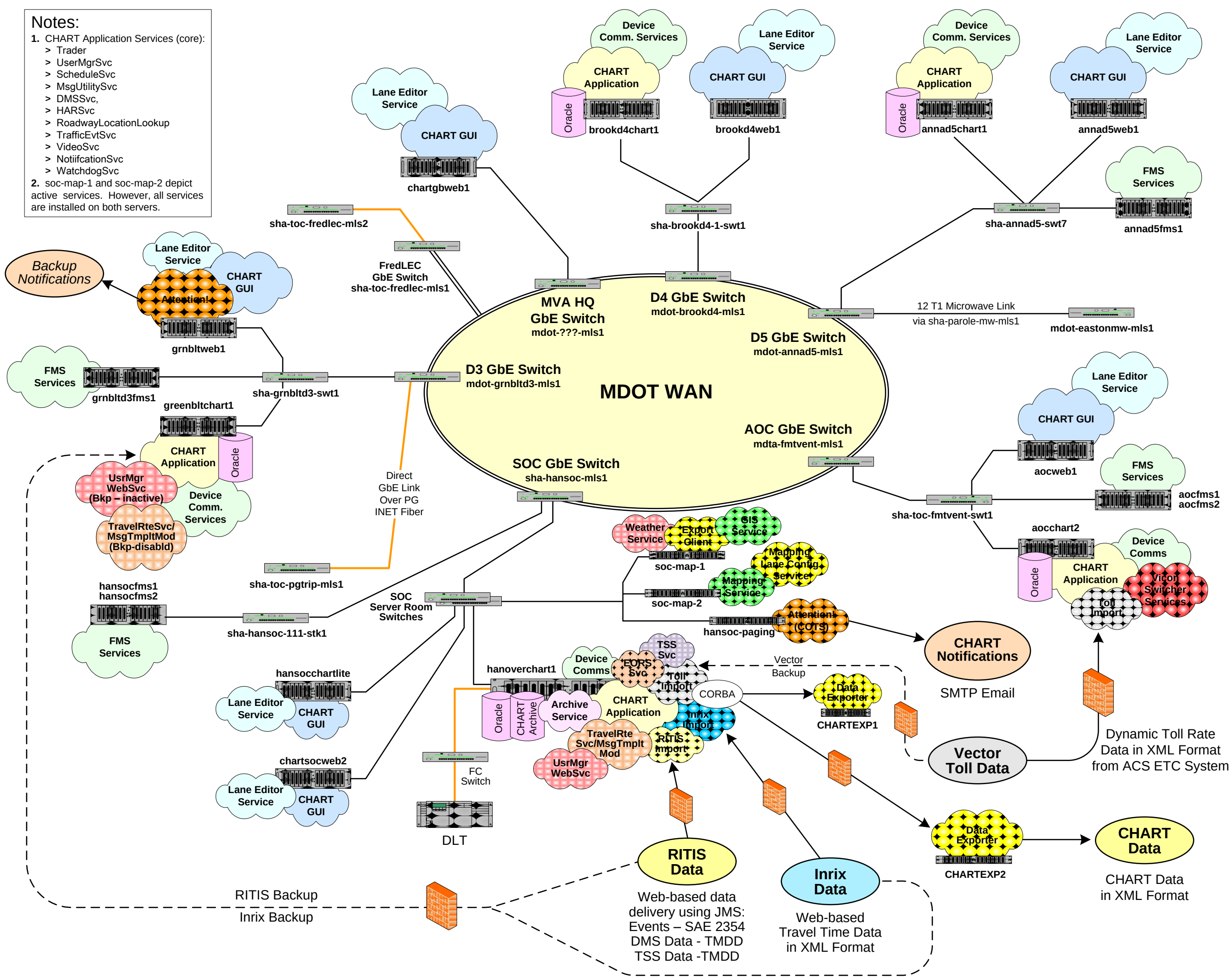


Figure 3-22 CHART Release 7 Server Installations

3.5.8 CHART Release 8

Release 8 adds TCP/IP-based control for the HIS DR1500 HAR and TCP/IP-based control for Shazam signs using HWG-ER02a IP relay switches. Additionally, while originally planned for incorporation in Release 9, Release 8 also includes the protocol handler for the new EIS G4 speed sensors. These enhancements are summarized in Table 3-12. Release 8 will also be deployed into CHART's recently virtualized server environment (Summer of 2011) as illustrated in Figure 3-23.

Table 3-12 CHART Release 8 Functions

CI	Subsystem	FUNCTIONALITY
CHART	Device Management (HAR)	Support for TCP/IP HAR
	Device Management (Shazam)	Support for TCP/IP relay switch to control Shazams.
	Device Management (TSS)	Support for EIS G4 RTMS, multi-drop communications

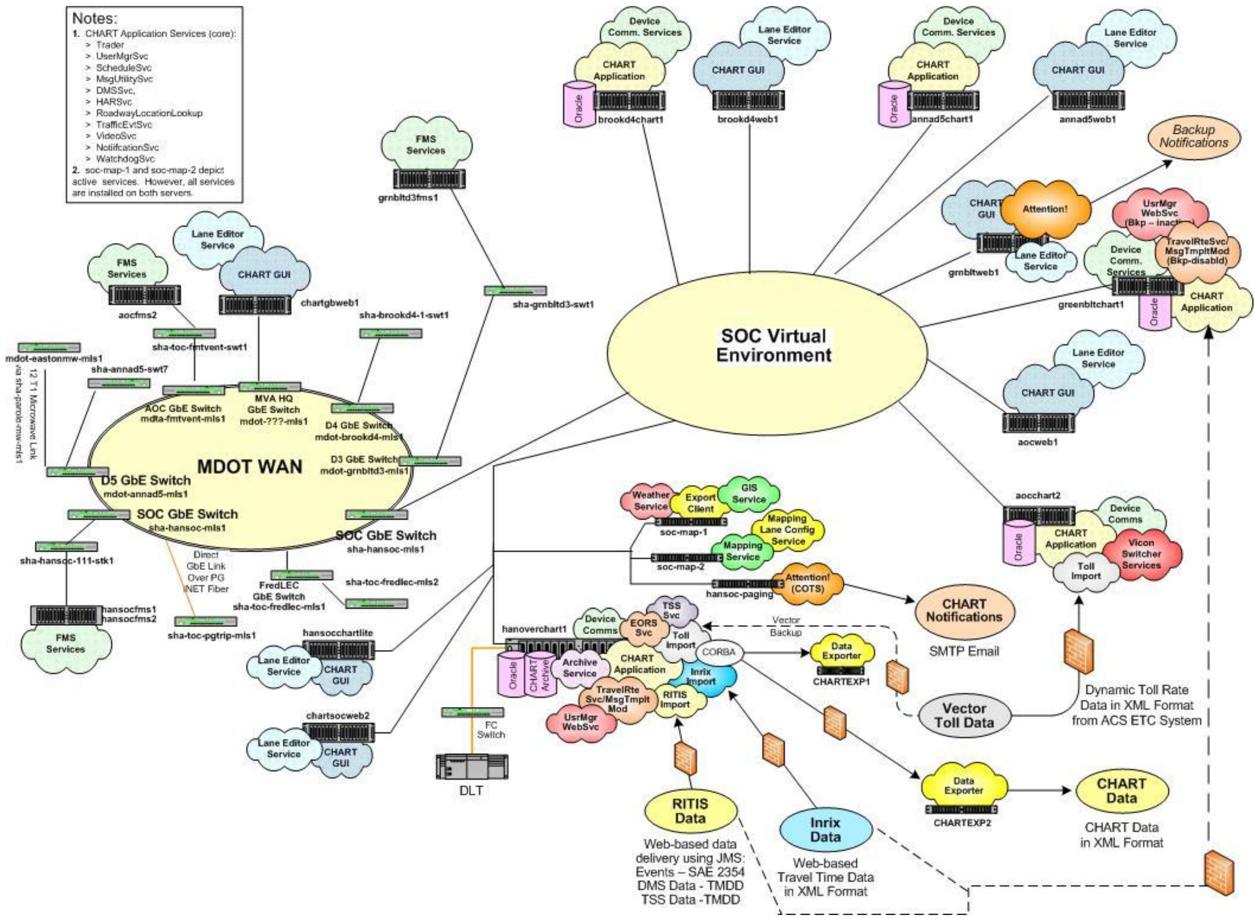


Figure 3-23 CHART Release 8 Server Installations

3.5.9 Future CHART Releases

Future releases include a wide variety of features as specified in the BAA. The table below shows some of the major functionality planned for upcoming releases and the subsystems affected.

Table 3-13 CHART Future Release Functions

CI	Subsystem	FUNCTIONALITY
CHART	Device (DMS)	Support for full matrix NTCIP DMS
	Device (Video)	Flash video on desktop
	Device (DMS/HAR), Traffic Event Management	Decision support: suggest DMS and HAR usage and messages for traffic event
	Device (Video), Traffic Event Management	Decision support: suggest camera usage, temporary tour for traffic event, monitor auto-mode to show traffic event video in area of responsibility

3.5.10 System Upgrade Strategy

Due to the geographic distribution of the system and the phased implementation and deployment approach, an upgrade strategy must be considered in the overall system design and architecture or significant disruption of the operational system could occur during the rollout of the new release. The design and architecture of the CHART system minimizes the impact to operations and provides flexibility in the scheduling of the installation of new hardware and software, particularly in the first release. This is accomplished in several ways.

- Standalone functionality – The CHART system is designed to operate in standalone mode on any particular server. This means that users connecting to that server may operate the CHART devices attached to that server, including cameras and monitors. This will allow the CHART system to be upgraded and phased in one server at a time if necessary. For example, if new types of devices, such as cameras and monitors are added to the CHART system, servers which have been upgraded will allow access to the new CHART devices. However, servers which have not been upgraded will continue to function with the previously existing CHART devices.
- Remote Installation – Through the use of COTS applications such as VNC, the installation of software can be performed remotely. Since the CHART GUI is browser based, with downloadable applets, no client side installations will be required for CHART system starting with Release 2.
- Modular Design – The modularity of the design allows CIs to be upgraded independently. The CHART and CHART application services, FMS services, CHART GUI applications, CHART Archive applications, and historically, all can and have been upgraded

independently of the others. Some dependencies do exist between CIs and in some cases a change in one CI may necessitate a corresponding change in another, but these dependencies are kept to a minimum and are isolated to the interfaces between CIs.

SYSTEM OPERATIONS DESIGN

4.1 Operations Scenarios

This section presents several operations scenarios to illustrate the operation of the system from a user's viewpoint.

4.1.1 Device Control

Device control is handled through the Traffic Event Management subsystem. The user interacts with this subsystem through the Event Management GUI (see Section 4.2.3). The use case diagram below illustrates the device control scenario. User requests for device control are placed in a device queue and are evaluated based on a set of business rules determining priority ranking. Messages associated with a traffic event are removed from the queue when the traffic event is closed. Note that CCTV cameras will not initially be controlled through Traffic Event Management.

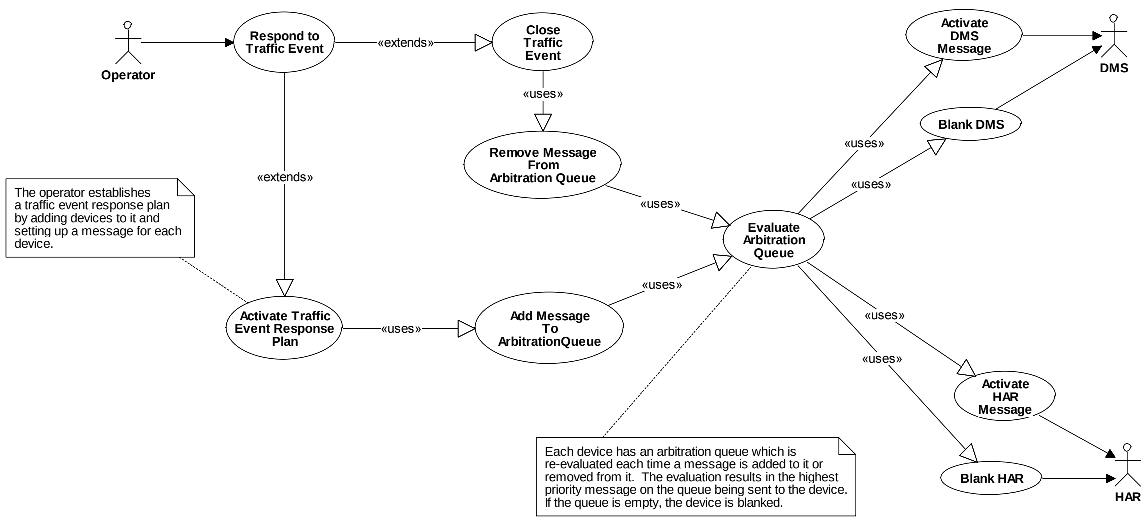


Figure 4-1. Device Control Use Case

4.1.2 Congestion Event

Congestion events are a type of traffic event. They are handled through the Traffic Event Management subsystem. The creation of a congestion event may occur automatically as a result of the evaluation of detector data or manually through the actions of an operator. The use case diagram below illustrates the congestion event scenario.

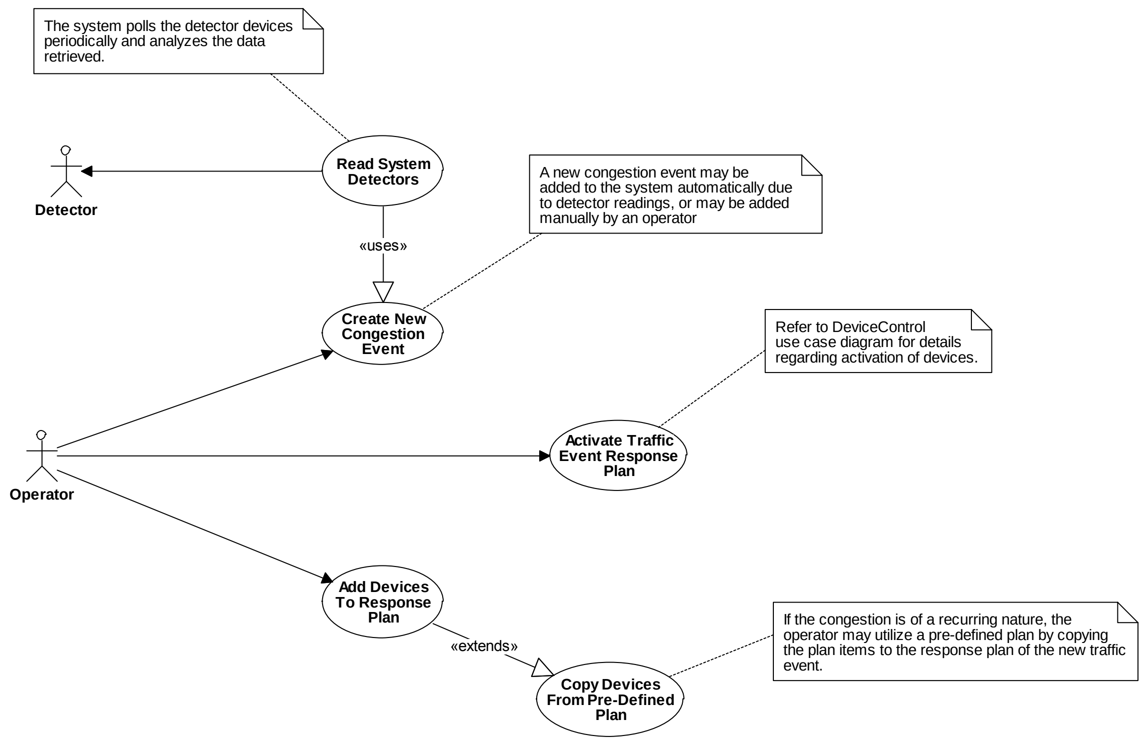


Figure 4-2 Congestion Event Use Case

4.1.3 CHART Server Failure

The failure of a CHART server or particular CHART service will be detected by the System Monitor subsystem and reported to an operator via a system alert (see use case diagram below). The operator will verify the problem and plan corrective actions. The operator will notify the Help Desk if appropriate (generally the Help Desk will already be alerted to the potential problem since the Help Desk has a monitors CHART components). If fail-over to a backup server is required the operator will implement the procedures for switching operations from the failed server to the selected backup server.

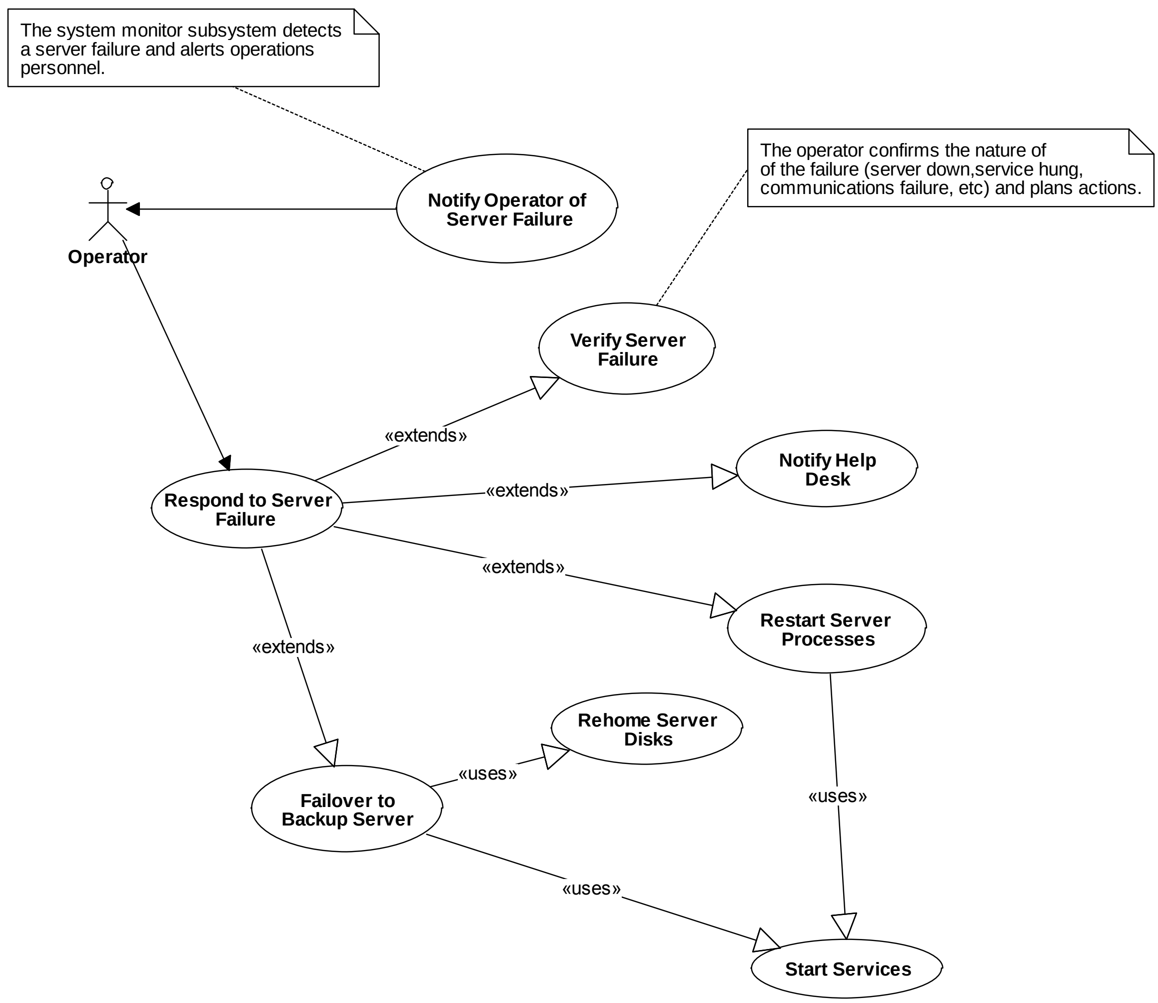


Figure 4-3 CHART Server Failure Use Case

4.2 User-System Interface

An essential component of a user interface framework is a well-designed data model. The data model is the core element that stores all data objects and allows other software components interested in the data that those objects provide to attach as observers. The model also includes a mechanism that allows an object to indicate that it has been modified and provide hints as to how it has been modified. In this way, the data model provides a mechanism by which objects may easily update in the system when they have received a state change event from a service application. The data model provides observers with the ability to attach with varying priority levels which determine the acceptable delay between the point in time when a data object detects a state change and that state change in conveyed to the end-user. This capability provides the interface to be updated very rapidly to attach at the highest priority level and can tolerate some delay to attach at lower priority levels. The data model aggregates updates during the delay period in order to avoid excessive repainting of the browser interface. Thus, if a particular object is modified three times within a 1 second period, a highest priority component may render all three state changes while a lower priority component may render only the final state of the object at the end of the period.

During the course of his/her work an end-user of the CHART system may need to execute commands that will take a significant amount of time for the system to execute. The user is provided with ability to view status of outstanding requests and commands; the outstanding requests view, and the failed requests view. The outstanding requests view provides the user with a list of operations that they have attempted that have not yet completed. When a command completes it will be removed from the outstanding requests view. If it completed with a failure, it will be added to the failed requests view. This allows an operator to view a list of system requests that have failed. Each entry in this window will contain a description of the request, the date and time the request was issued, and text describing the reason the command failed.

4.2.1 Archive System

The interface for the CHART Archive system is designed to support query and report generation for archive data. Both ad hoc and pre-defined queries and reports are supported. The Archive system interface will be Web-based so that client systems need only be able to support a Web browser in order to use the archive.

4.3 Operations Environment and Facilities

This section discusses the operations environment in terms of the facilities where CHART equipment is located and the system management and administration considerations for the operation of the system.

4.3.1 Facilities

This section presents the recommended deployment of hardware at each facility type and any special environmental considerations. Section 3.3 describes the hardware components and the environmental requirements.

4.3.1.1 Node Sites

CHART application and GUI web servers are primarily located at the SOC. The SOC houses the CHART virtual environment, currently hosting 5 CHART application nodes. Network node locations receive either single server or dual server configurations depending upon the degree of local recovery capabilities desired. The SOC at Hanover is a special case since it is a network node and the central site for the coordination of CHART activities. Figure 4-9 shows a typical server site installation. The list below describes the equipment to be deployed at each site.

- Hanover Statewide Operations Center (SOC) – HANOVERCHART1
    - Virtualized CHART application systems (5)
    - Two FMS servers
    - Web based Applications servers:
        - Virtualized CHART GUI Web Servers (6)
        - CHART Reporting Server
        - Virtualized CHART Mapping/DB Servers

        - CHART on the Web
- Authority Operations Center (AOC) – AOCCHART2
    - One FMS server
- SHA District 3 - Greenbelt – GREENBLTCHART1
    - One FMS Server
- Glen Burnie – CHARTGBWEB1
    - One CHART GUI Web Server

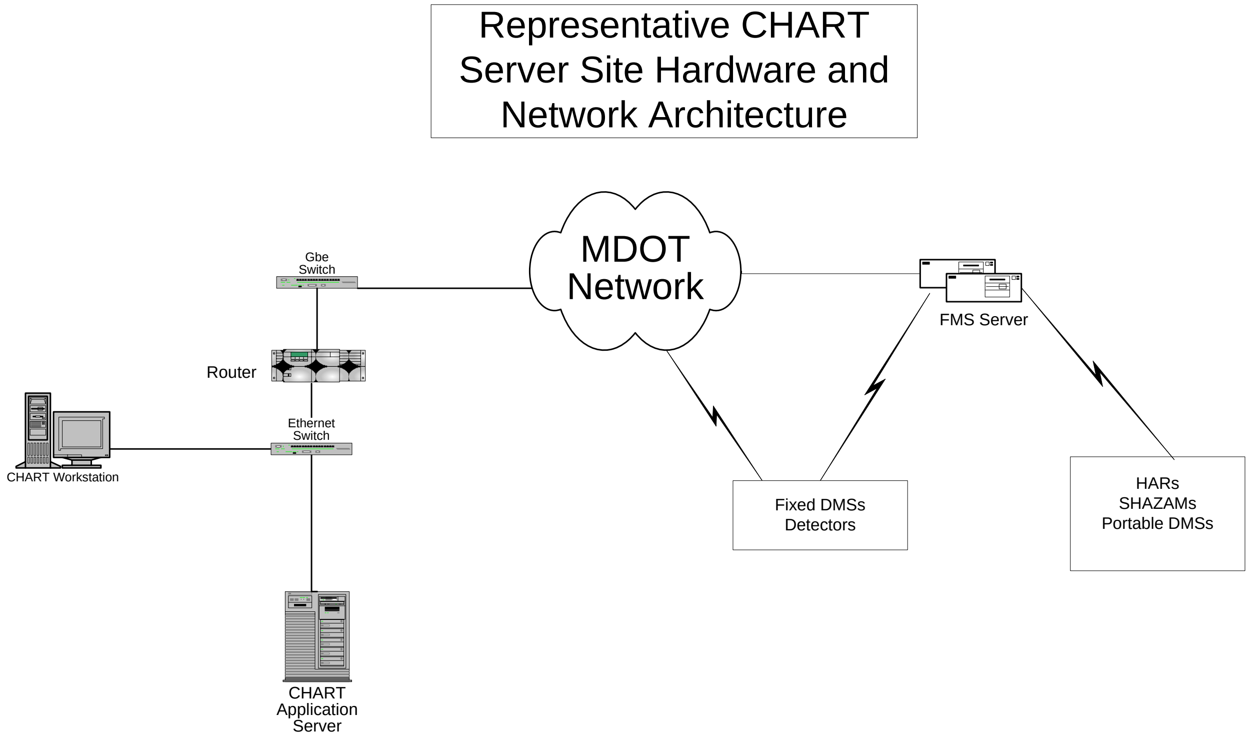


Figure 4-4 Representative CHART Server Site Hardware and Network Architecture

4.3.1.2 Traffic Operations Centers

Each TOC has one or two workstations. The number and configuration of the workstations will be determined on a case by case basis depending upon the activity level at the TOC and the available space. Figure 4-10 shows a typical TOC site installation.

4.3.1.3 Other CHART Client sites

Each client site will have workstations for use in accessing the CHART system. After Release 2, CHART workstations became synonymous with CHART GUI workstations. These workstations are able to perform all CHART functions, including CCTV camera control functions. The number and configuration of the workstations will be determined on a case by case basis depending upon the activity level at the site.

4.3.1.4 Maintenance Facilities

CHART will be run as an application on Enterprise Workstations.

4.3.1.5 Maryland State Police Barracks

Maryland State Police barracks will receive one workstation to be used to access CHART.

4.3.1.6 Equipment and Vehicle AVL Installation (future)

In addition to CHART interest in AVL, other SHA offices are investigating the deployment of AVL equipped vehicles (e.g. state and contractor operated snowplows). The actual number of AVL installations may reach several hundred. The equipment will be required to operate in the range of temperatures and weather conditions typically encountered during the year throughout Maryland. Both the in-vehicle and equipment attached AVL units are specifically designed for harsh environments. The operating temperatures for the example units described in Section 3.3.7 cover the expected range for CHART vehicles and equipment and the space requirements are small enough to not be an issue.

4.3.1.7 FMS Sites

The FMS servers are fielded in both environmentally controlled enclosures and also in non-environmentally controlled traffic control cabinets. The environmentally conrolled enclosures adhere to the following specifications:

- Temperature between 50 and 90 degrees Fahrenheit
- Non-condensing
- 8 – 90 percent humidity

The FMS servers are protected with an UPS with sufficient capacity to permit orderly system shutdown. Power is supplied to the UPS through an L5-30R receptacle.

Despite the use of environmentally controlled enclosures at some sites, the FMS hardware has been specified to be survivable in enclosures without environmental controls.

4.3.2 System Management and Support

This section discusses CHART system management activities and support provided for system monitoring and problem tracking.

4.3.2.1 Data Backup and Recovery

Data backup and recovery support is managed by two components within the CHART system. The Syncsort Backup Exec COTS package copies critical data from the database servers to the automated DLT Tape Library. Additionally, Oracle database backup utilities copy data to designated server backup folders on the network. The procedures responsible for performing the backups run automatically and require only periodic checks from CHART personnel to verify correct operation.

The system architecture and design minimizes the likelihood of having to recover an entire disk volume from tape backups. The use of RAID 1 and RAID 5 arrays and the replication of data in the system means that the system can perform self recovery in most instances. A more likely scenario would be the recovery of data due to corruption of some type. By taking periodic snapshots of the mission critical data and maintaining the data backups for a reasonable period of time a corrupted file could be restored to its last uncorrupted state.

4.3.2.2 System Monitoring

There are several levels of monitoring routinely performed on the CHART system. The CHART System Monitor subsystem monitors CHART services for availability and performs automatic restart attempts for non-responsive services. The System Monitor (as configured) generates

Alerts and Notifications when an automatic restart has been completed or when an automatic restart fails to correct a non-responsive service. General network health and performance are monitored by the NOC as part of the Maryland Network Management Services III contract. The system provides a way for operators to monitor system services status directly.

4.3.2.2.1 Performance Monitoring

Device failure status information is logged and can be reported on to provide device communications performance measures. Additional system level and network performance data are gathered by the NOC. CHART operational performance measures such as traffic event response time, incident cleared, etc are reported from the Traffic Event Management subsystem.

4.3.2.2.2 Problem Identification and Tracking

The CHART project uses the problem tracking tool ClearQuest, by Rational/IBM, to support CHART system problem reporting and tracking. Problems discovered prior to delivery of a release to operations are recorded as Level B problems and are handled as described in the document "Level B System Problem Reporting in ClearQuest, CHART-CM-TE-006, June 2009". Problems discovered in an operational release are recorded as Level A problems as described in the document "Level A System Problem Reporting in ClearQuest, CHART-CM-TE-004, June 2009".

Problems discovered by the NOC are logged in the NOC's Maximo system. Problems determined to be CHART software problems are used to create problem reports in the CHART ClearQuest system for tracking and resolution.

4.3.2.2.3 Security Management

Login access to CHART systems is controlled by the CHART User Management subsystem. Administrator privileges are required in order to modify user login information. A record of all changes that are made to user login information is logged in the operations log. Also user login/logout actions and failed login attempts are logged in the operations log.

All CHART systems are located behind firewalls to protect them from unauthorized access through the network. The presentation of data from CHART to the outside world is through a push of the data from CHART to external systems responsible for handling public access.

Because CHART is an application that resides on the MDOT Enterprise Network, all remote access is governed by the policies and procedures approved at the MDOT Security Working Group.

Access to CHART objects is controlled at the application level. The implementation of additional levels of access control for objects will be evaluated as necessary and as the state of the CORBA Security Services evolves.

Physical security of installation sites is the responsibility of the site owners and is not within the scope of this document.

4.3.2.3 Software Distribution

This section presents the procedures and processes used to control and manage the development and distribution of CHART software.

4.3.2.3.1 Configuration Management and Version Control

The overall configuration management plan for CHART is presented in the document "CHART Configuration Management Plan, PM-PL-004, August 2008." The specific objectives of the CHART CM program are to ensure that:

CHART hardware, software, and data configuration items (CIs) are appropriately selected and identified

CHART project baselines are established at the correct time

Changes to the CHART baselines are authorized, evaluated, implemented as approved, verified, and tracked in accordance with established procedures

Commercial off-the-shelf (COTS) tool upgrades are fully assessed and their impact evaluated

The status of CHART baselines and proposed and approved changes is accounted for and reported

Baseline and other required CM audits are carried out and the results reported

The integrity of the system design is maintained

The delivered system and all accompanying deliverables are accurately defined and described

The CHART development team is using Subversion for configuration management tool to support CHART software development. The configuration management policies and procedures for CHART software are defined in a set of standards and procedures documents. These standards and procedures documents are listed below.

- Review and Approval of COTS Upgrades, CHART-CM-PR-001, 2/2009

4.3.2.3.2 Software Installation

The installation of new versions of CHART software components is controlled through a Software Control Notice (SCN) as described in the document "Software Control Notice Procedure, June 2009". For new site installations the software components are installed and configured prior to integration of the system into the operational environment. Appendix A of the CHART R6 Operations and Maintenance Guide presents various options for performing software installations on operational system components.

4.3.2.4 Training

Training of CHART operations staff in the use of the CHART system is provided via several means.

- The system supports an online training capability in the form of field device simulators. Field device simulators or actual field devices set up for test purposes (e.g. a portable DMS) may be connected to the system and controlled by operations personnel in a training exercise.
- A training plan and training sessions with the CHART operations personnel are planned.

4.4 System Performance and Capacity Planning

This section presents system component sizing information and information on how the system has been designed to accommodate growth.

4.4.1 System Performance

The system performance requirements are listed in the CHART System Requirements Specification. The system is tested for compliance with these requirements with each delivered release. This section discusses several aspects of system performance and the how they have been accounted for in the design.

Performance estimates for the system have been developed using event scenarios and extrapolating based on expected growth in the number of events and in the number of traffic detection and messaging devices.

System performance can be broken into three areas of interest.

1. Server to Server CHART communications
2. Client to Server CHART communications
3. Server to Server Database replication traffic

4.4.1.1 Server to Server CHART communications

Server to Server CHART communications consists of messages between Traders, field device control and status messages, and bulk detector data. The table below represents a worst case characterization of the frequency and size of these messages. The numbers of devices are estimated at a possible full system build out. The first row of this table says there are 600 requests per hour that cause a Trader to request information from a Trader on another server and that the average size of requests is 20 bytes.

Table 4-1 Server to Server

Message Type	Frequency/ hour	Message Size	Number of devices	Total bytes
Trader	600	20 bytes	N/a	12KB
DMS control	4 per DMS	500 bytes	250	500KB
DMS status	6 per DMS	100 bytes	250	150KB
HAR control	1 per HAR	1 MB	50	50MB
HAR status	1 per HAR	20 bytes	50	1KB
Camera Display Request	2 per monitor	100 bytes	1500 (monitors)	300KB
Camera Control Request	1 per camera	100 bytes	500 (cameras)	50KB
Monitor status	2 per monitor	100 bytes	1500	300KB
Camera Status	7 per camera	100 bytes	500	350KB
SHAZAM poke	4 per SHAZAM	20 bytes	100	8KB
Detector status	12 per detector	38 bytes	500	228KB

Message Type	Frequency/ hour	Message Size	Number of devices	Total bytes
Bulk detector	1 per detector	2280 bytes	500	1.14MB
Travel/Toll Route updates	12 per Travel Route	500 bytes	200	1.2 MB

If we assume that all traffic either originates from or is received by a single CHART server and that none of the other servers are on the local network then the average data rate the CHART server and CHART Backbone network must handle is 115Kbps. This is well within the capabilities of the proposed CHART servers and the 3Mbps bandwidth available through the WAN. Normally this load would be spread over several CHART servers and much of the network traffic would be between CHART servers and FMS servers on the local network.

One observation that can be drawn from this table is that the FMS servers that communicate with HAR devices should be located on the CHART Backbone network and not on the frame relay.

4.4.1.2 Client to Server CHART communications

CHART GUI to server messages consists of Event service messages and user requests for certain services (such as library message creation, setting a message on a sign, streaming audio). The frequency with which a workstation will be updated with object status from the Event service is a configuration parameter. Also, the audio generated for streaming to a workstation will generally be of a low quality (and therefore smaller file size) than that created for download to a HAR. As in the Server to Server case we will use estimated worst case values here and assume a once per second update rate for the Event service, and HAR quality audio streamed to the workstation. The first row of this table says that every second a device state change is pushed out to 50 workstations with an average message size of 20 bytes.

Table 4-2 Client to Server

Message Type	Frequency/ hour	Message Size	Number of Workstations	Total bytes
Event service (device state change)	3600	20 bytes	50	3.6MB
User device control	5	250 bytes	50	62.5KB
Comm log updates	60	80 bytes	50	240KB
Streaming audio	4	1MB	10	40MB
TOTAL				44MB

4.4.1.3 Server to Server Database Replication

Database replication messages consist of the transfer of update requests from one server to another in order to synchronize specific database tables. The table below lists typical server to server update messages, frequency of that type of update occurring, and the estimated size.

Table 4-3 Server to Server Database Replication

Update Type	Frequency/ hour	Message Size	Total bytes
System Profile change	5	400	2KB
User configuration change	5	400	2 KB
Dictionary update	5	400	2KB
Event log update	3000	160 bytes	480KB
TOTAL			.5MB

The server to server and client to server traffic is much larger than the database replication traffic due almost entirely to the volume of data generated through text to speech conversion. Adding database replication to the overall volume does not significantly alter the total, raising it to just 217Kbps.

Based on these numbers, which have been derived by deliberately stretching the scope of the system, there are no resource bottlenecks on the MDOT backbone or CHART servers. Under normal operating conditions users will likely not notice any delays in the system even during high workload periods.

4.4.2 Text-to-Speech Conversion

Most messages used in CHART operations are less than two minutes duration, which result in a file size of less than 1MB.

4.4.3 Replication

The replication of database information puts an additional load on the network. Replication of information between sites that provide backup services in the event of remote site failures involves nearly full database replication. Operations log and device failure information is not replicated however all other database tables are.

When a row in a replicated table is updated the old value of the row and the updated values of the row are saved in the replication buffer for replication to the remote databases. A replication interval parameter controls how often replication occurs. At the expiration of the timer Oracle sends the replication information to the remote databases for update. The remote databases compare their current row values with the old row values received in the replication message and if there are no differences the rows are updated with the new values. As can be seen from this description the size of the replication messages is at most double the size of the original rows. For this reason the tables to be replicated are designed to minimize any unnecessary transfer of data.

4.4.4 System Growth

The CHART system distributed architecture is inherently scalable. New virtual or physical Servers and new shared resources (of types already known to the system) can be added to the system at any time without requiring software or hardware changes in the existing components. The number of shared resources that can be supported by the system is practically unlimited.

List of Acronyms

Following table lists the acronyms used in the document:

ACRONYM	DESCRIPTION
ADR	Automated Date Recorder
API	Applications Programming Interface
ASN.1	Abstract Notation One
ATM	Asynchronous Transfer Mode
CCTV	Closed Circuit Television
CHART	Coordinated Highways Action Response Team
CM	Configuration Management
CO	Central Office
CORBA	Common Object Request Broker Architecture
COTS	Commercial-off-the-shelf
CSC	Computer Sciences Corporation
CSU	Channel Service Unit
DLL	Dynamic Link Library
DMS	Dynamic Message Sign
DSU	Data Service Unit
EIS	Electronic Integrated Systems Inc.
FC	Fibre Channel
FMS	Field Management Station

ACRONYM	DESCRIPTION
HA	High Availability
IP	Internet Protocol
ISDN	Integrated Services Digital Network
ITS	Intelligent Transportation System
LATA	Local Access Transport Area
MD	Maryland
MDOT	Maryland Department of Transportation
MIB	Management Information Base
NOC	Network Operations Center
NTCIP	National Transportation Communication for ITS Protocol
OOM	Office of Maintenance
PBFI	PB Farradyne, Inc.
PIM	Partners in Motion
POC	Proof of Concept
RTMS	Remote Traffic Microwave Sensor
SAN	Storage Area Network
SCSI	Small Computer Storage Interconnect
SHA	State Highway Administration
SNMP	Simple Network Management Protocol
SOC	Statewide Operations Center

ACRONYM	DESCRIPTION
SONET	Synchronous Optical Network
SP	Service Pack
TCP	Transmission Control Protocol
TMDD	Transportation Management Data Dictionary
TNG	The Next Generation
TOC	Traffic Operations Center
TSR	Telecommunications Service Request
TTS	Text-to-Speech
UPS	Uninterruptable Power Supply
VMS	Variable Message Sign
WAN	Wide Area Network

Appendix A

A.1 Design Studies

This section provides information on analysis, prototyping, and trade studies dating from the initial system design effort to the current time.

A.1.1 C++/Java Performance Comparison

The purpose of this study was to compare the performance of the Java and C++ languages as they pertain to the development of an ITS control system. The tests included in this comparison were developed to investigate the performance characteristics of those language features that are most frequently utilized in the creation of an ITS control system. The study demonstrated that either language was a suitable candidate for the development of an ITS control system. The details of the study are found in the document, "C++/Java Performance Comparison for Distributed ITS Control Systems", M361-AR-002R0, March 30, 1999.

A.1.2 Java Feasibility

This study was originally conducted to investigate the feasibility of using the Java programming environment to develop the CHART system. The investigation was targeted at resolving what were identified as high-risk tasks for Java programming, specifically some areas related to the GUI. The details of the study are found in the document, "CHART II Java Feasibility Investigation", M361-AR-003R0, July 1, 1999.

A.1.3 CORBA ORB

This study was conducted to evaluate vendors of Common Object Request Broker Architecture (CORBA) Object Request Broker (ORB) products for use in the implementation of the CHART system. An initial field of twenty potential vendors was reduced to three candidates for evaluation. Based on how well each vendor scored on a set of ten criteria it was determined that the ORBacus product from Object Oriented Concepts best served the needs of CHART. This product is now owned by IONA Corporation. The details of the study are found in the document, "CORBA ORB Evaluation for CHART II", M361-AR-004R0, March 19, 1999.

A decision was made to replace ORBacus as part of CHART R2B3. CHART now uses a CHART customized version of JacORB, a freely available ORB.

A.1.4 Text-to-Speech Conversion

The generation of audio for download to Highway Advisory Radios (HARs) was identified as an area of improvement in the CHART system. It was desirable to have the capability in the CHART system to generate speech from text files in order to free the CHART operations personnel from having to manually record the audio for HARs. An evaluation of available text-to-speech (TTS) conversion applications was conducted to determine if the generation of speech from text files could be performed at a high enough quality for use in CHART.

There are two methods in general use in the industry for the conversion of text to speech. Rule-based systems use a set of rules for creating computer-generated speech from input text. Applications based on the concatenation algorithm method use a library of pre-recorded phonemes (speech fragments) to build audio from input text.

The quality of audio output was the main criteria for the evaluation of TTS applications. A number of rule-based applications and two concatenation-based applications were surveyed as potential candidates. A text file with a sample HAR message was created and a wav file generated from the text using each of the potential TTS applications. Based on a review of the output wav files by development and SHA personnel it was determined that none of the rule-based applications generated audio of sufficient quality for consideration. The product currently in use for CHART is the Nuance text to speech product, which is accessed via the Java MSSAPI interface.

A.1.5 Storage Area Network

A Storage Area Network (SAN) is an approach to data storage that moves storage systems from captive devices connected to dedicated servers to network devices in a peer-to-peer topology. The main purpose behind the installation of a SAN is to facilitate the growth of storage and servers independently of each other. A SAN uses Fibre Channel (FC) connections to provide higher transfer rates between devices than SCSI, and all SAN traffic runs independently of Local Area Network (LAN) traffic. In addition to the higher transfer rates, a SAN FC can operate over distances of 10km. A SAN can also serve as a key element in High Availability (HA) systems. By implementing a Tape Library as a SAN device, backups and restores can be done at any time of the day without affecting LAN performance. For these reasons a SAN was implemented to support the CHART system.

A.1.6 High Availability Architectures

The CHART II High Availability study was conducted to evaluate the options for providing increased availability in the CHART system. The details of the study are found in the document, "CHART II High Availability Study", M361-AR-009R0. Three options were evaluated and compared with a CHART baseline system. The three options were:

- Using Oracle Advanced Replication services to replicate the CHART database at CHART server sites.
- Using a Storage Area Network to maintain mirror copies of CHART server disks at the SOC.

Each of the three options has its advantages and disadvantages. As a result of the High Availability study, an interim configuration of Legato Co-Standby Advanced Availability Manager was implemented at the SOC. In December 2007, a Microsoft Cluster Services solution was implemented in conjunction with a SAN. Subsequently, however, a decision was made to not continue with any HA architecture at the SOC. This decision was primarily made because the CHART had become more fully realized as a truly distributed system across multiple nodes, thereby de-emphasizing the importance of the SOC in terms of the CHART system architecture.

A.1.7 Node Consolidation

In the spring of 2010, an effort to consolidate some of the CHART application server nodes was undertaken. There were multiple reasons for that effort including system stability, licensing costs, and a de-emphasis on the need for a distributed architecture to protect against network failure on the MDOT WAN.

The CHART application is designed to be fully distributed and scalable and can theoretically be expanded by adding additional nodes to the system. However, an increased communications overhead comes with that expansion. The CHART services must all communicate amongst each other via CORBA and adding additional nodes causes an exponential growth in the number of CORBA connections in the overall system. Each such connection introduces possible communications failure into the system which in turn creates potential stability problems.

Each application server node hosts an Oracle database instance and each Oracle instance carries a substantial licensing cost.

Part of the reason for the distributable architecture had been to allow nodes to function autonomously in the event that they were cut off from the rest of the nodes. Operators homed to an isolated node would still be able to operate their roadside devices and perform their traffic management tasks. However, over time, the WAN has proved to be very stable. The isolated node scenario has not occurred.

With that in mind, the initial node consolidation began in the summer of 2010. The number of CHART application nodes was reduced from eight to five. This improved overall system stability. Plans were made to eventually consolidate down to one node. Part of that consolidation effort includes a robust backup solution for both the application and the database. In addition, CHART application performance on a single node and backup failover scenarios must be studied and tested.

A.1.8 CHART Systems Database Strategic Plan

The purpose of this study, completed in April 2011, was to identify CHART systems database options that will maximize technical and financial benefit to SHA's business goals. The subsequent CHART Work Order Scope and Estimate Request Form requested the production of a white-paper type document to recommend a 5 year strategic plan for the CHART systems databases and also, after a check point with SHA, to create a plan including a schedule, assumptions and risks to implement the approved recommendations.

The assessment was approached using the Enterprise Architecture Framework as defined by the National Institute of Standards and Technology. This approach gives a holistic view of the enterprise. The Enterprise Architecture has 5 layers. The five layers are:

- Enterprise Business Architecture Layer
- Enterprise Information Architecture Layer
- Enterprise Application Architecture Layer
- Enterprise Application Integration Architecture Layer
- Enterprise Infrastructure Architecture Layer

The Enterprise Business Architecture Layer review for SHA was carried out previously by CSC and is reflected in the Business Area Architecture document: BAA Report Revision 6, January 2011. The recommendation for this layer was to continue on those specified in BAA.

The Enterprise Information Architecture Layer is comprised of the Presentation Management and Reports Management layers. In the Presentation Management layer of SHA, there are several Graphical User Interfaces identified. These are CHART GUI, EORS V2 GUI, EORS Legacy GUI CHARTWeb Desktop, CHARTWeb Mobile and the Intranet Map. The recommendation for this layer was to establish a single EORS GUI, establish CHART Analytics

GUI, establish an Attention Admin GUI and continue to use the following GUIs; CHARTWeb Mobile, CHARTWeb Desktop, CHART GUI, Intranet Map (ArcGIS) and implement a portal tool that will unify and enable a role-based Single-sign on.

In the Reports Management portion of the Enterprise Information Architecture, several report conduits were identified: SREE, SQL Server Reporting Service, Legacy Reporting Service, and Google Web Analytics Lite. The recommendation for this layer was to retire SREE, consolidate all SQL Server Reporting services, establish CHART dashboards, CHART Analytics (Business Intelligence tool) and use Google Urchin.

The Enterprise Application Architecture Layer is comprised of four core applications, which are CHART, EORS, CHARTWEB and MAPPING. The recommendation at this layer is to continue to have the applications remain independent of each other and integrate in the middleware layer.

The Enterprise Application Integration Architecture Layer is comprised of the middleware/IPC management layer. The CHART middleware management is using CORBA, TOMCAT, Apache, IIS/ASP/.NET, RSS, XML Web Services, and REST Web Services. The recommendation for this layer is that CHART is already on a good path and shall continue to use TOMCAT, IIS/ASP/.NET, RSS, and Apache. It was recommended that CHART implement an Enterprise Service Bus (ESB), establish web orchestration using BPEL, establish a form of Workflow mechanism using BPM, and establish a Web Services Manager and Service Registry. These middleware upgrades can possibly lead to the replacement of CORBA as an IPC solution in CHART in the future.

The Enterprise Infrastructure Architecture Layer is comprised of Database Management; Archive and Backup Management; and the physical Infrastructure Management. The recommendation for the Database Management portion was for SHA to use web services for communication and take the "Federated Option" which consists of the following components:

- Attention Database (paging system)
- A consolidated CHART Database
- CHART BG Database (SDE & Mapping)
- A consolidated EORS Database
- CHART Web Cache Database
- CHART Analytics Database (CHART-A)

This recommended approach would give SHA flexibility for growth, while systems and development cycles remain independent. It also provides a quicker patching cycle and keeps all application communication at the middleware layer. At the database layer, the recommendation is to consolidate databases where possible and implement an enterprise data governance strategy. The recommendation for the physical Infrastructure Management portion is for SHA to continue on the path of establishing VMware ESXi and upgrading to a more recent version of the Windows Server operating system. The ArcServe Backup product recommended by CHART's infrastructure team shall be implemented

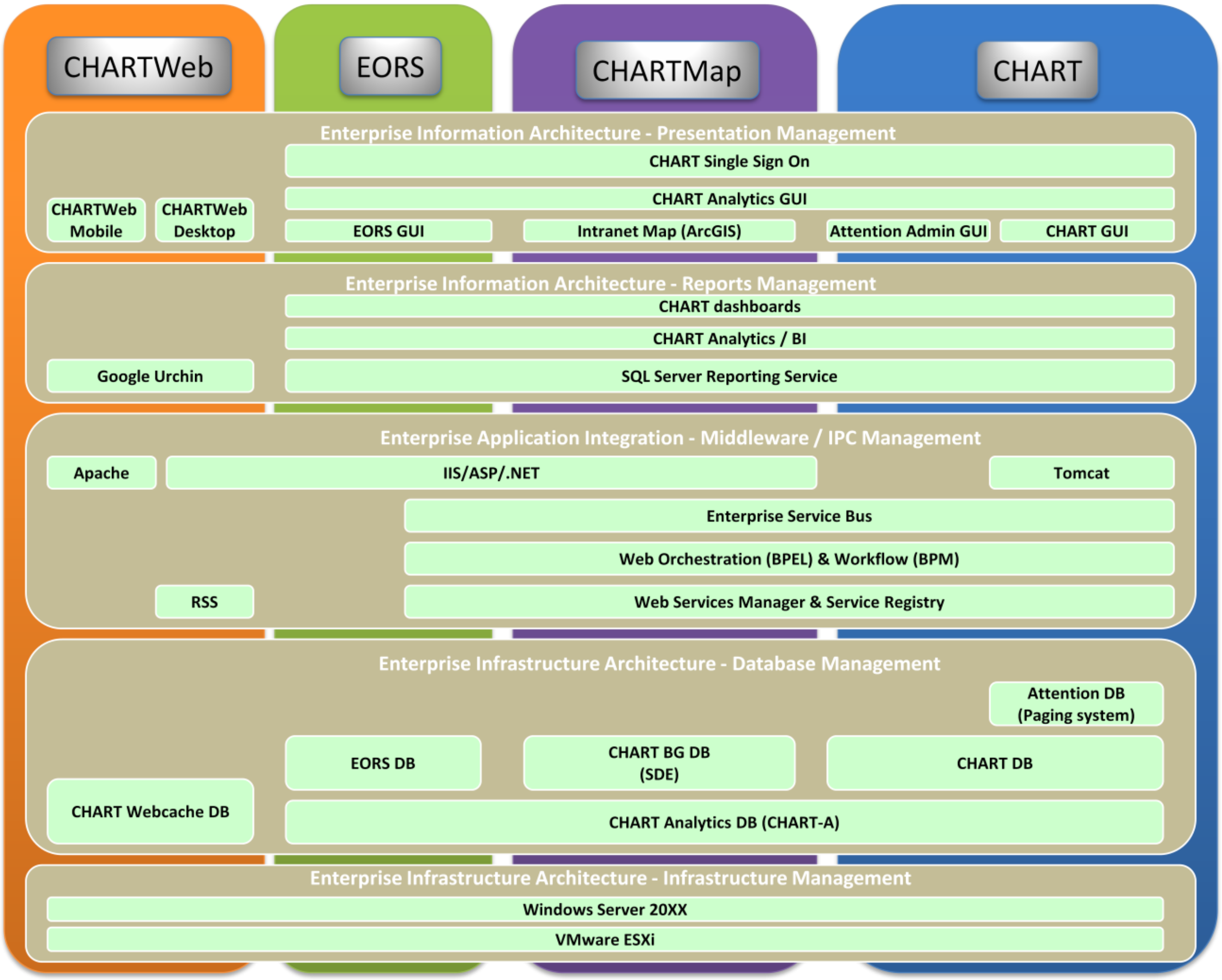


Figure A-1. Proposed CHART Architecture Revision

A.2 Major Prototypes

One of the key elements in our approach to designing the CHART system is prototyping. Prototyping is a valuable tool to establish proof of concept before implementation, it provides an opportunity for SHA to experience the look and feel of parts of the system in order to validate the design, and reduces risk by verifying technological solutions before committing funds for full deployment. Several prototypes have already been developed as part of the design process and several more prototype efforts are planned for the future. These are described below.

A.2.1 Event Logs

An Event Log prototype was developed to verify the user interface for event log management. This prototype consisted of a portion of the GUI for event management along with logic for performing some of the event management functions such as event creation, adding event entries, and closing out events. This work was performed as part of the high level design for CHART Release 1 Build 2. User feedback from the prototype was used to further refine the design.

A.2.2 HAR

A HAR prototype was developed to test the quality of broadcast for the latest generation of text to speech engines. Actual generated audio files and to verify the interface to the HAR. An actual HAR device was used in the prototype. Audio files were downloaded to the HAR and the quality of output monitored using the dial-up monitor port on the HAR (actual broadcast was not allowed with this device). Some of this work was later repeated when testing the quality of the Nuance text to speech product.

A.2.3 CCTV Distribution

A CCTV distribution prototype was developed to test the feasibility of a statewide system for the distribution of video. This prototype was also used to validate the architectural principal of CHART video being viewed by many different centers simultaneously. The prototype was also used to validate the ability to simultaneously control multiple camera types from a single user interface. The feasibility of this prototype was so successful that it was operational for 7 years. Release 2 of CHART included the distribution of video into the CHART system.

A.2.4 Automatic Vehicle Location

An Automatic Vehicle Location (AVL) capability in the CHART system was studied in calendar year 2000. A pilot program sponsored by the Department of Budget and Management (DBM) [now known as DoIT] evaluated two AVL products paired with two wireless communications providers.

A.2.5 Oracle to SQL Server

In 2011, some prototyping work was done to convert the CHART database from Oracle to SQL Server. The prototype converted DMS related tables and data from Oracle to SQL Server and then the CHART DMS service database driver was switched to work with SQL server. This work was done to help estimate the entire effort of using SQL Server for CHART.

A.2.6 Future Prototypes

A key element of the CHART design approach is prototyping. Prototyping will be used throughout the implementation of CHART whenever technology evaluation is needed or when early customer experience and feedback with a portion of the system is desired. This section describes plans for several future prototypes that have been identified.